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Classification, Description, and Dynamics of Plant
Communities Following Fire in the Taiga of Interior Alaska

(Final Report for BLM Contract No. 53500-CT2-224,
"Fire Effects Study".)

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1. Generalized Succession in the Black Spruce Type

1) Newly formed stage (5-10 years)
2) Seedling-spruce stage (10-20 years)

3) Mature spruce stage (20-30 years)

4) Spruce-hardwood stage (30-50 years)
5) Hardwood-dominated stage (50-100 years)

6) Mature black spruce stage (100-150 years)
7) Spruce-dominated stage (150-200 years)

8) Mature black spruce stage (200-300 years)
9) Black spruce stage (300-400 years)

10. General features of the Black Spruce Type
a) Occurs on black spruce bogs and swamps, often in association with other species.

b) Succession in the Black Spruce Type is characterized by the following stages:
1) Spruce stage (5-10 years)
2) Spruce-hardwood stage (10-20 years)
3) Hardwood stage (20-30 years)
4) Mature black spruce stage (30-40 years)

11. Succession in the Black Spruce Type
a) Spruce stage (5-10 years)
b) Spruce-hardwood stage (10-20 years)

12. Succession in the Black Spruce Type
a) Spruce stage (5-10 years)
b) Spruce-hardwood stage (10-20 years)

13. Succession in the Black Spruce Type
a) Spruce stage (5-10 years)
b) Spruce-hardwood stage (10-20 years)

14. Succession in the Black Spruce Type
a) Spruce stage (5-10 years)
b) Spruce-hardwood stage (10-20 years)

15. Succession in the Black Spruce Type
a) Spruce stage (5-10 years)
b) Spruce-hardwood stage (10-20 years)

16. Availability and utilization of the Black Spruce Type
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b) The Black Spruce Type is a valuable source of timber and other forest products.

c) The Black Spruce Type is a valuable source of timber and other forest products.

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SUMMARY

This study quantitatively and qualitatively describes the vegetation, browse utilization, and fuel composition in 125 mature and post-fire successional stands in the forested taiga of Alaska. These post-fire stands represent 31 recognizable fire-disturbed sites. The age since fire of 18 of these are known from records. The youngest stands were sampled one month after the fire and the oldest stands are 270 years in age.

Most of the sampled stands are located in the Tanana highlands with concentrations near Chicken, Delta, Harding Lake, the length of the Chena Hot Springs Highway, near Wickersham Dome, near Manley, near Hess Creek on the pipeline road to the Yukon, along the Steese Highway between Fairbanks and Chatanika, in Bonanza Creek Experimental Forest, and in the greater Fairbanks area. Additional stands were sampled along the Porcupine River, near McGrath, and near Black Rapids on the Richardson Highway.

The mature plant community types and the successional stages that precede them are defined and described. The woody plant species which are utilized by browsing animals are identified and their availability and utilization in the successional and mature stands are discussed. The woody fuels which occur on the forest floor are described.

The vegetation in the forested taiga of interior Alaska is divided into four broad climax types -- 1) white spruce, 2) upland black spruce, 3) lowland black spruce-bog, and 4) mixed spruce types. By the time most stands attain a post-fire age of 50 years they show characteristics of the climax type to which they are headed. This study, with the aid of clustering and ordination techniques, identified 14 distinct community types -- 4 on climax white spruce sites, 6 on climax black spruce sites, and 4 on climax mixed

SUMMARY

This study quantitatively and qualitatively described the vegetation, browse utilization, and fuel composition in 125 mature and post-fire successional stands in the forested tundra of Alaska. These post-fire stands represent 31 recognizable fire-disturbed sites. The age since fire of 18 of these are known from records. The youngest stands were sampled one month after the fire and the oldest stands are 270 years in age. Most of the sampled stands are located in the Tanana Highlands with concentrations near Chitina, Delta, Haverly Lake, the length of the Chena Hot Springs Highway, near Wickenburg Dam, near Hanley, near West Creek on the pipeline road to the Yukon, along the Steese Highway between Fairbanks and Chitina, in Bonanza Creek Experimental Forest, and in the greater Fairbanks area. Additional stands were sampled along the Porcupine River, near McGrath, and near Black Rapids on the Richardson Highway. The mature stand community types and the successional stages that precede them are defined and described. The woody plant species which are restricted by browsing animals are identified and their availability and utilization in the successional and mature stands are discussed. The woody fuels which occur on the forest floor are described. The vegetation in the forested tundra of interior Alaska is divided into four broad climax types -- 1) white spruce, 2) mixed black spruce, 3) larch and black spruce-bog, and 4) mixed spruce types. By the time most stands attain a post-fire age of 50 years they show characteristics of the climax type to which they are headed. This study, with the aid of clustering and ordination techniques, identified 18 distinct community types -- 8 on climax white spruce sites, 6 on climax black spruce sites, and 4 on climax mixed

spruce sites.

Those occurring on white spruce sites are:

- 1) Aspen/Viburnum/Twin-flower
- 2) Birch/Viburnum
- 3) White Spruce/Viburnum/Equisetum arvense
- 4) White Spruce/Twin-flower/Equisetum sylvaticum

Those occurring on black spruce sites are:

- 5) Aspen/Black Spruce/Cornus
- 6) Black Spruce-Aspen-Birch/Calamagrostis
- 7) Black Spruce/Lichen
- 8) Black Spruce/Rose/Peltigera
- 9) Black Spruce/Labrador-tea/Equisetum sylvaticum
- 10) Black Spruce/Narrow-leaf Labrador-tea/Sphagnum

Those occurring on mixed spruce sites are:

- 11) Birch-White Spruce-Black Spruce/Calamagrostis
- 12) Black Spruce-White Spruce/Grayleaf Willow/Hylocomium
- 13) Black Spruce-White Spruce/Labrador-tea/Geocaulon/Hylocomium-Pleurozium
- 14) Black Spruce-White Spruce/Lichen

The vegetation and site characteristics for each of these types are described.

These 14 mature community types represent the culmination of numerous stages that have followed disturbance, especially fire. Even though the successional series associated with each of these types is distinct, there is a general pattern to all those that occur within the same broad climax type. The following 5 stages were identified as occurring on climax white

Those occurring on white spruce sites are:

- 1) Aspen/Viburnum/Twin-flower
- 2) Black/Viburnum
- 3) White Spruce/Viburnum/Quercus arvensis
- 4) White Spruce/Twin-flower/Quercus sylvatica

Those occurring on black spruce sites are:

- 5) Aspen/Black Spruce/Quercus
- 6) Black Spruce-Aspen-Black/Cornus-ostrea
- 7) Black Spruce/Alnus
- 8) Black Spruce/Black/Betula

- 9) Black Spruce/Black-leaf/Quercus sylvatica
- 10) Black Spruce/Black-leaf/Black-leaf/Quercus

Those occurring on mixed spruce sites are:

- 11) Birch-White Spruce-Black Spruce/Cornus-ostrea
- 12) Black Spruce-White Spruce/Black Willow/Hydrangea
- 13) Black Spruce-White Spruce/Black-leaf/Quercus/Hydrangea
- 14) Black Spruce-White Spruce/Alnus

The vegetation and site characteristics for each of these types are

described.

These 14 mature community types represent the culmination of numerous stages that have followed disturbance, essentially fire. Even though the successional series associated with each of these types is distinct, there is a general pattern to all those that occur within the same broad climatic zone. The following 5 stages were identified as occurring on climax white

spruce sites:

- 1) Moss-herb-seedling stage (1-5 post-fire years)
- 2) Willow or shrub stage (6-25 post-fire years)
- 3) Dense hardwood stage (26-50 post-fire years)
- 4) Mature aspen and thinning birch stage (51-100 post-fire years)
- 5) Mature birch and climax white spruce stage (>100 post-fire years)

The following six stages were identified as occurring on climax black spruce sites:

- 1) Newly burned stage (0 post-fire years)
- 2) Seedling-sucker stage (1-5 post-fire years)
- 3) Willow or shrub stage (6-25 post-fire years)
- 4) Dense hardwood and small diameter black spruce stage (26-50 post-fire years)
- 5) Dense black spruce/Pleurozium stage (51-100 post-fire years)
- 6) Mature black spruce/feathermoss stage (>100 post-fire years)

Figures 21 and 22 graph the most important features occurring in each stage on climax white spruce sites and show how they change through time. Figures 27 and 28 do the same for the stages occurring on black spruce sites.

This report also discusses how the succession culminating in the following mature community types differs from these two generalized patterns:

- 1) Aspen/Viburnum/Twin-flower, 2) Birch/Viburnum, 3) White Spruce/Viburnum/Equisetum arvense, 4) White Spruce/Twin-flower/Equisetum sylvaticum,
- 5) Aspen/Black Spruce/Cornus, 6) Black Spruce-Aspen-Birch/Calamagrostis,
- 7) Black Spruce/Lichen, 8) Black Spruce/Labrador-tea/Equisetum sylvaticum,

spruce sites

- 1) Post-fire seedling stage (1-5 post-fire years)
- 2) Willow or shrub stage (5-25 post-fire years)
- 3) Dense hardwood stage (25-50 post-fire years)
- 4) Mature aspen and thinning birch stage (50-100 post-fire years)
- 5) Mature birch and climax white spruce stage (>100 post-fire years)

The following six stages were identified as occurring on climax black

spruce sites

- 1) Newly burned stage (0 post-fire years)
- 2) Seedling-sucker stage (1-5 post-fire years)
- 3) Willow or shrub stage (5-25 post-fire years)
- 4) Dense hardwood and small diameter black spruce stage (25-50 post-fire years)
- 5) Dense black spruce/feathermoose stage (50-100 post-fire years)
- 6) Mature black spruce/feathermoose stage (>100 post-fire years)

Figures 21 and 22 graph the most important features occurring in each stage on climax white spruce sites and show how they change through time. Figures 23 and 24 do the same for the stages occurring on black spruce

sites.

This report also discusses how the succession culminating in the following mature community types differs from these two generalized patterns:

- 1) Aspen/Willow/Twin-flower, 2) Birch/Willow, 3) White Spruce/Willow, 4) Aspen/Willow/Twin-flower/Feathermoose, 5) Black Spruce/Aspen-Birch/Feathermoose, 6) Black Spruce/Willow, 7) Black Spruce/Aspen, 8) Black Spruce/Aspen-Willow, 9) Black Spruce/Aspen-Willow/Feathermoose, 10) Black Spruce/Aspen-Willow/Feathermoose, 11) Black Spruce/Aspen-Willow/Feathermoose, 12) Black Spruce/Aspen-Willow/Feathermoose, 13) Black Spruce/Aspen-Willow/Feathermoose, 14) Black Spruce/Aspen-Willow/Feathermoose, 15) Black Spruce/Aspen-Willow/Feathermoose, 16) Black Spruce/Aspen-Willow/Feathermoose, 17) Black Spruce/Aspen-Willow/Feathermoose, 18) Black Spruce/Aspen-Willow/Feathermoose, 19) Black Spruce/Aspen-Willow/Feathermoose, 20) Black Spruce/Aspen-Willow/Feathermoose, 21) Black Spruce/Aspen-Willow/Feathermoose, 22) Black Spruce/Aspen-Willow/Feathermoose, 23) Black Spruce/Aspen-Willow/Feathermoose, 24) Black Spruce/Aspen-Willow/Feathermoose, 25) Black Spruce/Aspen-Willow/Feathermoose, 26) Black Spruce/Aspen-Willow/Feathermoose, 27) Black Spruce/Aspen-Willow/Feathermoose, 28) Black Spruce/Aspen-Willow/Feathermoose, 29) Black Spruce/Aspen-Willow/Feathermoose, 30) Black Spruce/Aspen-Willow/Feathermoose, 31) Black Spruce/Aspen-Willow/Feathermoose, 32) Black Spruce/Aspen-Willow/Feathermoose, 33) Black Spruce/Aspen-Willow/Feathermoose, 34) Black Spruce/Aspen-Willow/Feathermoose, 35) Black Spruce/Aspen-Willow/Feathermoose, 36) Black Spruce/Aspen-Willow/Feathermoose, 37) Black Spruce/Aspen-Willow/Feathermoose, 38) Black Spruce/Aspen-Willow/Feathermoose, 39) Black Spruce/Aspen-Willow/Feathermoose, 40) Black Spruce/Aspen-Willow/Feathermoose, 41) Black Spruce/Aspen-Willow/Feathermoose, 42) Black Spruce/Aspen-Willow/Feathermoose, 43) Black Spruce/Aspen-Willow/Feathermoose, 44) Black Spruce/Aspen-Willow/Feathermoose, 45) Black Spruce/Aspen-Willow/Feathermoose, 46) Black Spruce/Aspen-Willow/Feathermoose, 47) Black Spruce/Aspen-Willow/Feathermoose, 48) Black Spruce/Aspen-Willow/Feathermoose, 49) Black Spruce/Aspen-Willow/Feathermoose, 50) Black Spruce/Aspen-Willow/Feathermoose, 51) Black Spruce/Aspen-Willow/Feathermoose, 52) Black Spruce/Aspen-Willow/Feathermoose, 53) Black Spruce/Aspen-Willow/Feathermoose, 54) Black Spruce/Aspen-Willow/Feathermoose, 55) Black Spruce/Aspen-Willow/Feathermoose, 56) Black Spruce/Aspen-Willow/Feathermoose, 57) Black Spruce/Aspen-Willow/Feathermoose, 58) Black Spruce/Aspen-Willow/Feathermoose, 59) Black Spruce/Aspen-Willow/Feathermoose, 60) Black Spruce/Aspen-Willow/Feathermoose, 61) Black Spruce/Aspen-Willow/Feathermoose, 62) Black Spruce/Aspen-Willow/Feathermoose, 63) Black Spruce/Aspen-Willow/Feathermoose, 64) Black Spruce/Aspen-Willow/Feathermoose, 65) Black Spruce/Aspen-Willow/Feathermoose, 66) Black Spruce/Aspen-Willow/Feathermoose, 67) Black Spruce/Aspen-Willow/Feathermoose, 68) Black Spruce/Aspen-Willow/Feathermoose, 69) Black Spruce/Aspen-Willow/Feathermoose, 70) Black Spruce/Aspen-Willow/Feathermoose, 71) Black Spruce/Aspen-Willow/Feathermoose, 72) Black Spruce/Aspen-Willow/Feathermoose, 73) Black Spruce/Aspen-Willow/Feathermoose, 74) Black Spruce/Aspen-Willow/Feathermoose, 75) Black Spruce/Aspen-Willow/Feathermoose, 76) Black Spruce/Aspen-Willow/Feathermoose, 77) Black Spruce/Aspen-Willow/Feathermoose, 78) Black Spruce/Aspen-Willow/Feathermoose, 79) Black Spruce/Aspen-Willow/Feathermoose, 80) Black Spruce/Aspen-Willow/Feathermoose, 81) Black Spruce/Aspen-Willow/Feathermoose, 82) Black Spruce/Aspen-Willow/Feathermoose, 83) Black Spruce/Aspen-Willow/Feathermoose, 84) Black Spruce/Aspen-Willow/Feathermoose, 85) Black Spruce/Aspen-Willow/Feathermoose, 86) Black Spruce/Aspen-Willow/Feathermoose, 87) Black Spruce/Aspen-Willow/Feathermoose, 88) Black Spruce/Aspen-Willow/Feathermoose, 89) Black Spruce/Aspen-Willow/Feathermoose, 90) Black Spruce/Aspen-Willow/Feathermoose, 91) Black Spruce/Aspen-Willow/Feathermoose, 92) Black Spruce/Aspen-Willow/Feathermoose, 93) Black Spruce/Aspen-Willow/Feathermoose, 94) Black Spruce/Aspen-Willow/Feathermoose, 95) Black Spruce/Aspen-Willow/Feathermoose, 96) Black Spruce/Aspen-Willow/Feathermoose, 97) Black Spruce/Aspen-Willow/Feathermoose, 98) Black Spruce/Aspen-Willow/Feathermoose, 99) Black Spruce/Aspen-Willow/Feathermoose, 100) Black Spruce/Aspen-Willow/Feathermoose.

and 8) Black Spruce/Narrow-leaf Labrador-tea/Sphagnum. A few comments are given on how succession on young, scraped firelines differs from that of burned areas.

The woody plant species which are browsed by animals include six tree, seven willow, five non-willow tall shrub, and eleven low shrub species. Of these, 28 species occur on black spruce sites and 17 on white spruce sites.

Throughout all the stands on both white spruce and black spruce climax site types where browse occurred, the immature tree species are most dense and most heavily utilized in the younger successional stages (1-5 post-fire years), the willows are heavily utilized during the next older stages (6-25 and 26-50 post-fire years), while the non-willow shrubs are most dense and most utilized in the more mature stages (51-100 and > 100 post-fire years). More willow stems occur and more are removed during the 6-25 post-fire year period; however, the greatest percent utilization of the willows occurs during the 26-50 post-fire year period.

Aspen, birch, balsam poplar, Bebb willow, grayleaf willow, littletree willow, highbush cranberry, rose, and green alder are the preferred browse species. In addition, feltleaf willow, Scouler willow, diamondleaf willow, resin birch, low blueberry willow, shrubby cinquefoil, Labrador-tea, and blueberry are generally utilized when they occur. Other species were only occasionally browsed.

Browsing utilization of these species is more general on climax black spruce sites than it is on climax white spruce sites. However, in terms of percent utilization the browsed willow and non-willow shrub species growing on white spruce sites are more thoroughly utilized than those growing on the

and 8) Black Spruce/Narrow-leaf Larch/Siberian Fir. A few comments are

given on how succession on young, scattered stands differs from that of

burned areas.

The woody plant species which are browsed by animals include six trees,

green willow, tree non-willow (all shrub, and eleven low shrub species. Of

these, 28 species occur on black spruce sites and 17 on white spruce sites.

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(1-5 post-fire years), the willows are heavily utilized during the next

other stages (6-25 and 26-50 post-fire years), while the non-willow shrubs

are most dense and most utilized in the more mature stages (51-100 and > 100

post-fire years). Some willow stems occur and some are removed during the

6-25 post-fire year period; however, the greatest percent utilization of

the willows occurs during the 26-50 post-fire year period.

Aspen, birch, balsam poplar, larch, willow, meadow willow, litchium

willow, highbush cranberry, rose, and green alder are the preferred browse

species. In addition, larch, larch willow, larch, diamondleaf willow,

red-barked, low-bush willow, shrubby cinquefoil, Labrador-tea, and

highbush are generally utilized when they occur. Other species were

only occasionally browsed.

Succession utilization of these species is more general on climax black

spruce sites than it is on climax white spruce sites. However, in terms of

percent utilization the browsed willow and non-willow shrub species growing on

white spruce sites are more thoroughly utilized than those growing on the

upland black spruce sites while just the reverse occurs for the browsed tree species which are slightly better utilized on the black spruce sites.

The fuel data is summarized for each of the successional stages in the following five canopy or overstory types: 1) pure hardwood, 2) pure black spruce, 3) pure white spruce, 4) hardwood-dominated, and 5) black spruce-dominated types.

In the 1-5 post-fire year period pure birch stands have more slash fuel, both small and large diameter, than do the pure black spruce stands. (Hardwood stands average 16.3 T/ha total slash and black spruce stands 4.9 T/ha.) In the 6-25 post-fire year period the pure hardwood stands have the greatest volume of large slash fuel (hardwood stands average 28.8 T/ha and black spruce stands 10.2 T/ha of large slash) and black spruce stands contain the greatest volume of small slash (black spruce stands average 7.4 T/ha and hardwood stands 5.3 T/ha of small slash). In the 26-50, 51-100 and 100 post-fire year periods the pure black spruce stands have more slash fuel, both small and large, than do the hardwood stands. The total volumes for black spruce stands are 8.1, 5.7, and 7.3 T/ha, while for the hardwood stands they are 5.4, 5.2, and 5.0 T/ha, respectively, in the 26-50, 51-100, and >100 post-fire periods.

Stands of mixed hardwood-spruce composition display trends which are between these two. Hardwood-dominated stands are similar to the pure hardwood stands and the spruce-dominated stands are more similar to the pure black spruce stands, with one exception. More large slash is produced in the 51-100 post-fire year period in both types of mixed stands than might be expected.

Standing fuel becomes slash. Immediately after the fire and the point

upland black spruce sites while the reverse occurs for the mixed

tree species which are slightly better utilized on the black spruce sites.

The fuel data is summarized for each of the successional stages in

the following five canopy or overstory types: 1) pure hardwood, 2) pure

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In the 1-5 post-fire year period pure black spruce stands have more slash

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the greatest volume of small slash (black spruce stands average 7.4 t/ha and

hardwood stands 2.3 t/ha of small slash). In the 26-50, 51-100, and 101

post-fire year periods the pure black spruce stands have more slash fuel.

Both small and large, than do the hardwood stands. The total volume for

black spruce stands are 8.1, 6.7, and 7.3 t/ha, while for the hardwood stands

they are 2.1, 2.3, and 2.0 t/ha, respectively, in the 26-50, 51-100, and

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Stands of mixed hardwood-spruce composition display trends which are

between these two. Hardwood-dominated stands are similar to the pure

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pure black spruce stands, with one exception. More large slash is produced

in the 21-100 post-fire year period in both types of mixed stands than

might be expected.

Standing fuel becomes slash. Immediately after the fire and the point

when stands become overmature are two periods when the number of standing dead trees is greatest. Dead branches develop on living trees as they mature. These are soon shed on hardwood trees and their lower boles become and stay branchless; however, they remain on the black spruce for many years. Even in the older spruce stands, they may be found within 3 dm of the ground.

In general, the older the stands become, the thicker the leaf, green moss, brown moss, and organic layers become. Most of the non-woody fuel in spruce stands is green moss, brown moss and lichen. The organic layer is usually deeper in spruce stands than it is in hardwood stands.

During the period 1940-1969, the average annual burn was 1 million acres (Harty and Frank 1963; Berman 1971; Vaseck 1973). During this period 70% of the fires were man caused but 40% of the acreage burned resulted from the lightning-caused fires. Delaplanche estimated the annual burn since 1950 to be about 100,000 acres or 100,000 hectares. Vaseck thought this is a significant reduction, fire is still a part of the Interior Alaskan environment.

Man has been interested in the effects of fire on the vegetation in Interior Alaska for some time. In the early 1900's Harold Curt studied the ecological effects of fire in Interior Alaska. In 1955 he wrote, "The forests of Interior Alaska present a mosaic of types resulting from the effects of forest fires and from variations in site." This work stood alone in this field until 1973 when Vaseck in a paper, "Wildfire in the Tundra of Alaska", summarized the current status of knowledge on fire effects in the Alaskan tundra.

Unpublished paper presented by Delaplanche, S. at the "Canadian Alaskan Seminar on Research Needs in Fire Ecology and Fire Management in the North", Fairbanks and Fairbanks, Alaska, October 1-10, 1970. Sponsored by The Northern American Forestry Commission, Fire Management Study Group.

when stands become overmature are two periods when the number of standing dead trees is greatest. Dead branches develop on living trees as they mature. These are soon shed on hardwood trees and their inner poles become and stay branchless; however, they remain on the black spruce for many years. Even in the older spruce stands, they may be found within 2 dm of the ground. In general, the older the stands become, the thicker the leaf, green moss, brown moss, and organic layer become. Most of the non-woody fuel in spruce stands is green moss, brown moss and lichen. The organic layer is usually deeper in spruce stands than it is in hardwood stands.

I. INTRODUCTION AND PROBLEM

Wildfire (both lightning and man caused) has always been a part of the interior Alaskan scene. Aboriginal man is thought to have caused wildfires (Lutz 1959). During the Gold Rush era man-caused fires burned large acreages. Because no formal records existed, the impact of this burning can only be estimated. For the period 1889-1940, Lutz (1953) estimated that one million acres burned annually; while Barney (1971) stated that an annual burn of 1.5-2.5 million acres would be more correct.

More recent wildfire statistics show a reduction in the acreages burned. For the period 1940-1969, the average annual burn was 1 million acres (Hardy and Frank 1963; Barney 1971; Viereck 1973). During this period 70% of the fires were man caused but 78% of the acreage burned resulted from the lightning-caused fires. DeLeonardis considers the annual burn since 1969 to be about 400,000 acres or 160,000 hectares. ^{1/} Even though this is a significant reduction, fire is still a part of the interior Alaskan environment.

Man has been interested in the effects of fire on the vegetation in interior Alaska for some time. In the early 1950's Harold Lutz studied the ecological effects of fire in interior Alaska. In 1956 he wrote, "The forests of interior Alaska present a mosaic of types resulting from the effects of forest fires and from variations in site." This work stood alone in this field until 1973 when Viereck in a paper, "Wildfire in the Taiga of Alaska", summarized the current status of knowledge on fire effects in the Alaskan taiga.

^{1/} Unpublished paper presented by DeLeonardis, S. at the "Canadian-Alaskan Seminar on Research Needs in Fire Ecology and Fire Management in the North", Anchorage and Fairbanks, Alaska, October 7-10, 1975. Sponsored by the Northern American Forestry Commission, Fire Management Study Group.

1. INTRODUCTION AND PROBLEM

Wildfires (both lightning and man caused) has always been a part of the Interior Alaskan scene. Alaskan man is thought to have caused the Interior Alaskan scene. During the 1940's man caused fires burned 1,000,000 acres (Lutz 1953). Because no formal records existed, the impact of this burning can only be estimated. For the period 1892-1940, Lutz (1953) estimated that one million acres burned annually; while Barney (1971) stated that an annual burn of 1.5-2.5 million acres would be more correct. More recent wildfire statistics show a reduction in the acreage burned. For the period 1940-1963, the average annual burn was 1 million acres (Barney and Frank 1963; Barney 1971; Vitek 1973). During this period 70% of the fires were man caused but 25% of the acreage burned resulted from the lightning-caused fires. The concept of considering the annual burn since 1959 to be about 400,000 acres or 160,000 hectares. Even though this is a significant reduction, fire is still a part of the Interior Alaskan environment.

Man has been interested in the effects of fire on the vegetation in Interior Alaska for some time. In the early 1920's Harold Lutz studied the ecological effects of fire in Interior Alaska. In 1936 he wrote, "The forests of Interior Alaska present a mosaic of types resulting from the effects of forest fires and from variations in site." This work alone in this field until 1973 when Vitek in a paper, "Wildfire in the State of Alaska", summarized the current status of knowledge on fire effects in the Alaskan tundra.

Man has also been involved in the management, at least the curtailment, of fire, for some time. The Bureau of Land Management (BLM) started keeping fire records in the early forties. Since then control of wildfires has become a large scale activity. In 1971 the symposium "Fire in the Northern Environment" (Slaughter et al 1971) summarized the current status of fire research and management in Alaska and northern Canada.

Management agencies are now interested in such questions as the following: Should all fires be extinguished? Are there assets associated with wildfire, i.e. will it help to improve moose browse, melt permafrost, renew caribou feeding grounds? Is fire needed and/or necessary to maintain certain types of vegetation? Can fire improve the vegetation? If so can we predict where and when the pay-offs from the assets will be greatest? In short, can fire, fire prevention and fire use be managed as a tool to aid in the attainment of present goals? What are the alternatives and what are the responses of the vegetation to the alternatives?

BLM recognized the need for more information to answer some of these questions and in December, 1971 contracted with the Institute of Northern Forestry to initiate fire effects studies. This paper reports on the results of these studies.

II. OBJECTIVES

The objectives of this project are threefold: 1. to identify the most fire-prone plant community types; 2. to describe in quantitative and qualitative terms the vegetation in each of these types; 3. to show the effect of time-since-burn on the vegetation, the amount and type of forest floor fuels, the amount of woody browse available and the degree to which the browse is utilized in each of these types. In short, to

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Northern Environment" (Singer et al 1971) summarized the current status

of fire research and management in Alaska and northern Canada.

Management agencies are now interested in such questions as the follow-

ing: Should we fire to extinguish? Are there assets associated with

wildfire, i.e. will it help to improve range lands, soil productivity, water

quality, etc? Is fire needed and/or necessary to maintain certain

types of vegetation? Can fire improve the vegetation? If so can we predict

where and when the fire will be greatest? In short,

can fire, fire prevention and fire be managed as a tool to aid in the

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Forestry to initiate the wildfire studies. This paper reports on the results

of these studies.

1. OBJECTIVES

The objectives of this project are therefore: 1. to identify the

most fire-prone plant community types; 2. to describe the qualitative

and quantitative values of the vegetation in each of these types; 3. to study

the effect of fire on the vegetation, the amount and type of

forest fires, the amount of woody biomass available and the degree

to which the biomass is utilized in each of these types. In short, to

provide the quantitative and qualitative data to describe the various "stages" in plant succession.

III. METHODS

A. SITE

Interior Alaska is a very large area; bounded on the north by the Brooks Range, on the south by the Alaska Range, on the west by the Seward Peninsula, and on the east by the Canadian border. Most of the sample plots were located in the Tanana highlands with concentrations of stands near Chicken on the Taylor Highway, Delta on the Alcan Highway, Harding Lake on the Richardson Highway, the length of the Chena Hot Springs Highway, near Wickersham Dome and Manley on the Elliott Highway, near Hess Creek on the pipeline road to the Yukon, along the Steese Highway between Fairbanks and Chatanika, in Bonanza Creek Experimental Forest on the Nenana Highway, and in the greater Fairbanks area. Additional stands were sampled along the Porcupine River in the northeastern part of the interior, around McGrath in the southwestern portion of the interior and near Black Rapids on the Richardson Highway.

Upland soils in interior Alaska are of various origins. Much of the area, including most of the Tanana highlands and the Upper Kuskokwim Valley, is covered with loess to varying depths. This wind blown silt was blown from vegetation-free bars of braided glacial rivers during Illinoian and Wisconsin times, although some is still being deposited today (Pewé '68).

Much of the upland area, especially the north-facing or well-shaded slopes, have frozen soils. In some locations this permafrost layer is continuous over large areas while in others it is restricted to small patches

provide the quantitative and qualitative data to describe the various "stages" in plant succession.

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surrounded by unfrozen soils. In some areas it underlies a shallow active layer (the layer that thaws each year) and in others the annual thaw may be several meters deep.

Valley bottom soils in interior Alaska are frequently a mixture of retransported loess and peat. Péwé (1968) calls this soil "organic-rich fetid perennially frozen muck."

Riverbottom soils, on the other hand contain much sand and gravel in addition to the silt. In this newly deposited alluvium permafrost is absent.

B. FIELD

Sites of thirty-one previous fires were visited. Dates of 18 of these fires were documented by written or oral records. They are: Porcupine Fire - 1950, Badger Road Fire - 1958, Chena Dome Fire - 1958, Healy Fire - 1958, Chena Hot Springs Road Fire - 1957-1958, Murphy Dome Fire - 1958, Good Pasture Fire - 1958, Goldstream Fire - 1966, Standard Fire - 1966, Harding Lake - 1966, Hess Creek Fire - 1966, Cement Creek or Chicken Fire - 1966, Steese-Hotsprings Road Junction Fire - 1968, Manley Fire - 1969, Wick-ersham Dome Fire - 1971, Ganes Creek Fire - 1971, Nixon Flats Fire - 1971. The post-fire-age of the rest were obtained from tree ring counts of post-fire grown trees or post-fire scar tree ring counts of trees that survived the fire.

1. Vegetation Description. -- Forested areas of taiga in interior Alaska can be divided into four main climax, habitat or site types. That is, if an area is undisturbed (without fires, floods, or clearing, etc.) one can predict the vegetation type that will prevail. These four broad

surrounded by unfrozen soils. In some areas it underlies a thin ice active layer. The layer that thaws each year) and in others the annual thaw may be several meters deep.

Valley bottom soils in interior Alaska are frequently a mixture of retransported loess and peat. Börs (1963) calls this soil "organic-rich" and generally "frozen muck."

Riverbottom soils, on the other hand contain much sand and gravel. In addition to the silt, in this newly deposited alluvium gravel is absent.

2. FIRE

Since at thirty-one previous times were stated, dates of 15 of these times were documented by written or oral records. They are: Fortunate Fire - 1950, Badger Road Fire - 1952, Chena River Fire - 1952, Healy Fire - 1952, Chena Hot Springs Road Fire - 1953-1954, Murphy River Fire - 1954, Good Pasture Fire - 1955, Goldstream Fire - 1955, Steward Fire - 1955, Harding Lake - 1955, Hot Creek Fire - 1955, Chena Creek or Chena Fire - 1955, Stearns-Hot Springs Road Junction Fire - 1955, Hanley Fire - 1955, Wick-erham River Fire - 1957, Gans Creek Fire - 1957, Nixon Lake Fire - 1957. The post-fire age of the forest was obtained from tree ring counts of post-fire grown trees or post-fire tree ring counts of trees that survived the fire.

1. Vegetation Description. -- Forested areas of tundra in interior Alaska can be divided into four main classes, habitat or site types. That is, it is an area in which the vegetation is of a certain type (e.g., spruce, etc.) one can predict the vegetation type that will prevail. These four broad

climax types are 1) the white spruce type, 2) the upland black spruce type, 3) the black spruce-bog cyclic type, and 4) the mixed white spruce-black spruce type. The white spruce climax type occurs on sites which are warm and well-drained, usually they have a southerly exposure. The upland black spruce climax type occurs on sites which are cool, and frequently underlain by permafrost. The black spruce-bog cyclic climax type occurs on cool lowland and upland valley sites where drainage is poor. The fourth type, the mixed spruce climax type occurs where the white spruce type and either of the black spruce types overlap. A more lengthy discussion of each of these site types occurs in the results section of this paper.

Fire can occur in each of these types; however, some appear more fire-prone than others. The most fire-prone appears to be the upland black spruce type. This is followed in decreasing order by the white spruce type, the mixed spruce type and lastly the black spruce-bog type.

Most of the work done for this project was limited to the three most fire-prone types, the white spruce type, the black spruce type and the mixed spruce type. Within these three climax types we identified the following mature vegetation community types: 1) Aspen/Viburnum/Twin-flower, 2) Birch/Viburnum, 3) White Spruce/Viburnum/Equisetum arvense, 4) White Spruce/Twin-flower/ Equisetum sylvaticum, 5) Aspen-Black Spruce/Cornus, 6) Black Spruce-Aspen-Birch/Calamagrostis, 7) Black Spruce/Lichen, 8) Black Spruce/Rose/Peltigera, 9) Black Spruce/Labrador-tea/Equisetum sylvaticum, 10) Black Spruce/Narrow-leaf Labrador-tea/Sphagnum, 11) Birch-White Spruce-Black Spruce/Calamagrostis, 12) Black Spruce-White Spruce/Grayleaf Willow/Hylocomium, 13) Black Spruce-White Spruce/Labrador-tea/Geocaulon/Hylocomium-Pleurozium, and 14) Black Spruce-White Spruce/Lichen. Types 1-4 occur on

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climax white spruce sites, 5-10 occur on climax black spruce sites while types 11-14 occur on climax mixed spruce sites.

With increasing age after fire each stand changes in the composition of its plant species or in the growth form of the vegetation, in the type and amount of fire fuel present, and in the type and amount of animal forage present. This study showed that grouping the data into the following post-fire age class groups most clearly focused distinct successional changes: 1-5 years, 6-25 years, 26-50 years, 51-100 years, and > 100 years.

A total of 125 stands were studied. Table one shows how they separated out in the analysis of the data. Some age classes of several of the successional type groupings are unrepresented. This is unfortunate but to be expected since a fore-knowledge of all group types was lacking. It also illustrates that not all types occur with the same frequency.

Before a given stand was studied it had to meet the following requirements: 1) at least 2 hectares (5 acres) in size, 2) homogeneous in vegetation composition and 3) of uniform topography. The sampling design and vegetation description methods have been patterned after those used by Ohmann and Ream (1971a) who did similar work in Boundary Waters Canoe Area of northern Minnesota. Briefly, within each stand a grid with 20 points was established. At each point a nest of plots was used to estimate percent cover for each plant species and density per hectare of tall shrub, tree seedlings, saplings and mature trees. For the mosses, lichens, herbs, and low shrubs a 1 m² plot was used, for the tall shrubs and tree seedlings a 4 m² circular plot was employed, while a point-centered quarter plotless method (Cottam and Curtis ('56)) was used to sample the trees, mature, sapling and standing dead. Some modifications were made. These have been

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Table 1. Breakdown of interior Alaskan stands that were surveyed by climax type, community type, and successional stage (years-since-burn) categories.

Climax Type - Community Type	Successional Stage Years-Since-Burn						Type Total
	0	1-5	6-25	26-50	51-100	>100	
WS - 1) AS/VIB/T-F ^{1/}		2	4	2	2	x ^{2/}	10
WS - 2) B/VIB		2	5	2	2	2	13
WS - 3) WS/VIB/E. arv				1		3	4
WS - 4) WS/T-F/Equ.						2	2
WS - Site Total	0	4	9	5	4	7	29
BS - 5) A-BS/COR		8	4	3	3	x ^{2/}	18
BS - 6) BS-A-B/CAL		1	5	3	3		12
BS - 7) BS/LIC	1	3	3	2	4		13
BS - 8) BS/R/PEL						3	3
BS - 9) BS/L-T/E. syl	2	14	3	3	3		25
BS -10) BS/N-L L-T/SPH		4	1			3	8
BS - (bladed firelines)	1	1	1				3
BS - Site Total	4	31	17	11	13	6	82
M -11) B-WS-BS/CAL						1	1
M -12) BS-WS/GW/HYL						2	2
M -13) BS-WS-/L-T/Geo/HYL-PLE						2	2
M -14) BS-WS/LIC	2	1	2	2		2	9
M - Site Total	2	1	2	2		7	14
Grand Total							125

FOOTNOTES:

^{1/} Community type names are abbreviated. Refer to the following page for their full name.

^{2/} Aspen trees seldom attain ages of >100 years so these types are rare.

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Key to Abbreviated Community Type Names

WS = White Spruce

- 1) A/VIB/T-F = Aspen/Viburnum/Twin-flower
- 2) B/VIB = Birch/Viburnum
- 3) WS/VIB/E. arv = White Spruce/Viburnum/Equisetum arvense
- 4) WS/T-F/E. syl = White Spruce/Twin-flower/Equisetum sylvaticum

BS = Black Spruce

- 5) A-BS/COR = Aspen-Black Spruce/Cornus
- 6) BS-A-B/CAL = Black Spruce-Aspen-Birch/Calamagrostis
- 7) BS/LIC = Black Spruce/Lichen
- 8) BS/R/PEL = Black Spruce/Rose/Peltigera
- 9) BS/L-T/E. syl = Black Spruce/Labrador-tea/Equisetum sylvaticum
- 10) BS/N-L L-T/SPH = Black Spruce/Narrow-leaf Labrador-tea/Sphagnum

MS = Mixed Spruce

- 11) B-WS-BS/CAL = Birch-White Spruce-Black Spruce/Calamagrostis
- 12) BS-WS/GW/HYL = Black Spruce-White Spruce/Grayleaf Willow/Hylocomium
- 13) BS-WS/L-T/GEO/HYL-PEL = Black Spruce-White Spruce/Labrador-tea/Geocaulon/Hylocomium-Pleurozium
- 14) BS-WS/LIC = Black Spruce/White Spruce/Lichen

described in the 1973 study plan for this project.^{2/} I have also included a detailed methods section in the appendix of this report.

2. Browse Availability and Utilization. -- The density and cover values taken in the vegetation survey were assumed to represent the availability of each species for browse animals. To quantify the amount of utilization made of each species, three height classes and four utilization classes were established. The utilization classes are 0, 1-33% utilization, 34-66% utilization and 67-99% utilization.^{3/} The height classes are 0-1 m, 1-2 m, and 2 m. After all the stems of each species within each height class were inspected for teeth marks and breakage due to browsing, a utilization class was recorded for each species-height class category.

3. Ignition Potential of the Forest Floor. -- Slash fuel, standing fuel, leaf litter, mosses, lichens as well as the organic layer itself are all components of the forest which will burn if they are sufficiently dry. If there is sufficient volume of these fuels they will carry a fire away from the point of fire origin. However, if there is insufficient volume of fuels or if there is a great volume of moist green vegetation, the fire may wane. If a fire manager could predict the occurrence and volume of each of these factors, his decisions could be more realistic. As an aid to fire managers then, we tried to inventory the forest floor fuels that were present in each of the stands we surveyed. To do this

^{2/} Typed study plan (Foote, 1973) on file at the Institute of Northern Forestry, Fairbanks.

^{3/} Personal communication with C.T. Cushwa, then Program Leader at the Institute of Northern Forestry, Fairbanks.

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Personal communication with C.T. Kusawa, then Program Leader at the Institute of Northern Forestry, Fairbanks.

we followed the methods developed by James Brown (1974)^{4/}. The actual methods which we used have been described in study plans^{5/}. We were specifically interested in 1) the slash fuel potential, and 2) standing fuel potential, and 3) the litter fuel potential. Each of these items will be discussed.

1) Slash Fuel: The volume of ground slash was estimated by using a series of 10 meter long transects (4-5 per stand). Along each the number of twigs that intersected a given length of each transect was counted by diameter class. Twigs less than 6 mm (1/4") were counted in the first one or two meter(s) of each transect, twigs .6-2.5 cm (1/4" - 1") were counted in the first two meters of each transect, twigs 2.5-7.6 cm (1" - 3") were counted in the first three meters of each transect. Logs 7.6 cm (3") diameter intersecting the 10 meter transects were counted and their diameter at the point of the intersection recorded.

The volume of aerial fuel was determined in the same way. The aerial transect was a plane touching the ground transect at the soil surface and extending two vertical meters into the air. A plumbob was used to visually determine whether or not an aerial twig actually intersected the plane.

The height of the slash fuel was recorded at three points along the transect, at 0-1 dm, 10-11 dm, and 20-21 dm from the point of origin.

2) Standing Fuels: Five living trees and five living saplings near the origin of each transect were used to obtain information on the standing

^{4/} Personal communication of unpublished methods in 1971 between Noste and Brown were utilized in developing the field techniques used in this study.

^{5/} Typed study plans (Noste - 1972, Foote - 1973) on file at the Institute of Northern Forestry, Fairbanks.

we followed the methods developed by James Brown (1974). The actual methods which we used have been described in study plan². We were specifically interested in 1) the slash fuel potential, and 2) standing fuel potential, and 3) the litter fuel potential. Each of these items will be discussed.

1) Slash Fuel: The volume of ground slash was estimated by using a series of 10 meter long transects (4-5 per stand). Along each the number of chips that intersected a given length of each transect was counted by diameter class. Chips less than 5 cm (1/4") were counted in the first one or two meter(s) of each transect, chips 5.5-6 cm (1/4" - 1") were counted in the first two meters of each transect, chips 6.5-7.5 cm (1" - 3") were counted in the first three meters of each transect, chips 7.5 cm (3") diameter intersecting the 10 meter transects were counted and their diameter at the point of the intersection recorded.

The volume of aerial fuel was determined in the same way. The aerial transect was a plane touching the ground closest to the soil surface and extending two vertical meters into the air. A pinhook was used to visually determine whether or not an aerial chip actually intersected the plane. The height of the slash fuel was recorded at three points along the transect, at 0-1 dm, 10-11 dm, and 20-21 dm from the point of origin.

2) Standing Fuel: Five living trees and five living saplings near the origin of each transect were used to obtain information on the standing

² Personal communication of unpublished methods in 1977 between Hoste and Brown were utilized in developing the field techniques used in this study.

³ Typed study plan (Hoste - 1973, Forest - 1973) on file at the Institute of Northern Forestry, Fairbanks.

fuel potential. The distance from the ground to 1) the lowest dead branch and 2) the lowest living branch were measured and recorded to the nearest dm.

3) Litter Fuels: At a representative spot somewhere along each transect the depth of each type of litter was measured to the nearest centimeter. Leaf litter and duff, green moss, brown moss and duff, and lichen were considered types of litter. In addition the depth of the organic soil layer was measured at the side of the hole from which the soil samples were taken.

Once the vegetation types and age-groups were established the fuel information was summarized for each group.

4. Soil Parameters. -- Soil characteristics influence the type of vegetation that grows on any site. The presence of and depth to permafrost, the thickness of the organic layer, the physical characteristics of the mineral soil, the pH of the soil and the nutrients in the soil are all important parameters to consider in interpreting vegetation types. The depth to permafrost was measured at each m^2 plot by pushing a probe into the soil until it hit a frozen layer. The thickness of the organic layer was obtained near each m^2 plot by cutting the vegetative mat and organic soil with a knife. The depth from the surface to continuous mineral soil was interpreted as the organic layer. The remaining parameters all require laboratory analysis. Within each stand 1-3 soil pits were dug. Samples from both the organic soils and the mineral soils were collected. In the laboratory these samples were oven-dried, sieved and sent out for particle size and nutrient analysis. Depending on the availability of the laboratories some soils were sent to the University of Alaska Forest Soils Laboratory

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in Fairbanks and some were sent to the USFS Forestry Sciences Soils Laboratory at Corvallis, Oregon.

5. Additional Stand Information. -- Tree cores, voucher plant specimens and photographs were obtained. The tree cores were taken as close to the base of the tree as the increment bore and the presence of solid wood would allow. Fifteen cores were selected from each tree stand, 5 from the largest and potentially oldest trees in the stand and 10 from predetermined trees used in the tree inventory, usually the live tree in quadrant one of all even numbered plots. The rings on the cores were then counted in the laboratory with the use of a dissecting microscope.

For taxonomic purposes woody species names used were from "Alaska Trees and Shrubs" (Viereck and Little '72), herbaceous species names used were from "Flora of Alaska" (Hultén '68), while for the cryptogams "A Checklist of the Mosses of Alaska" (Worley and Watuski '70) and "A Fourth Checklist of the Lichens of the Continent of United States and Canada" (Hale and Culbertson '73) were used. Difficult species identifications were determined by Alan Batton, Dr. David Murray, and Barbara Murray all of the University of Alaska Herbarium. Voucher plant specimens were collected and will be deposited in the University of Alaska Herbarium (ALA). Common plant names used were from "Alaska Trees and Shrubs", (Viereck and Little '72), "Flora of Alaska" (Hultén), and "Anderson's Flora of Alaska" (Welsh '74). A complete list of species encountered in this study is given in appendix A.

Photographs included two to three general views of the interior stands and two to three views of typical plots. These proved useful in later work.

C. Data Analysis

A series of computer programs assisted in the analysis of the qualitative and quantitative vegetation data. Figure 1 gives an overview of the stages in the analysis.

1. Stand Summaries. -- A set of four computer programs - HERBSUM, SHRUBSUM, SEEDSUM AND TREESUM - was used to summarize the quantitative and qualitative data collected on the vegetation in each stand. The important variables are percent frequency, average cover, species, density per hectare, seedlings per hectare, and basal area per hectare.

The equations used in obtaining these values and sample outputs from these programs are given in sections B & C of the appendix. The output from these programs is used in various combinations for the input in the analytical and community summary programs.

2. Basis of Analysis. -- Percent frequency-of-occurrence of species was the measure used to compare sampled stands with each other. This measure has been used by many (Gittens 1965a, b; Orloci 1966, Austin and Orloci 1966; Yarranton and Beasleigh 1968). Ohmann and Ream (1971b) and Grigal and Ohmann (1975) used it in similar work done in the Boundary Waters Canoe Area in Northern Minnesota where it proved satisfactory in both ordinating and classifying the stands they studied. The data were analyzed by multivariate techniques. The computational equations used are listed in the appendix and in earlier papers (Orloci 1967, Grigal and Goldstein 1971; Goldstein and Grigal 1972a, b).

3. Data Reduction. -- Regional flora is variable and many species occur only incidentally. The 170 species which were encountered in this study proved too numerous for the computer to handle when using the multivar-

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Mature Stand Data Set

PROGRAMS: HERBSUM SHRUSUM SEEDSUM TREESUM

Stand Summaries

PROGRAM: SCREEN

Selected Species

Numerical Classification
-Cluster Analysis-
(within-group-dispersion)

PROGRAM: ORLOC

Stand Groups
=Tentative Community Types
Dendrogram(Fig. 6)

Canonical Analysis
-Ordination-

PROGRAM: CANAL

Regions of Space for Community Types

Figure 1.--Flow chart showing steps in procedure used to objectively identify plant community types from white spruce sites and black spruce sites in interior Alaska.

iate techniques needed to classify and to ordinate the data. Grigal and Ohmann use a computer program called SCREEN to make the reduction of species both objective and quantitative^{6/}. We used the program in 1973 on the data collected from 1971-1973.

SCREEN ranks the species in the data set first on six different criteria and secondly on the average of all criteria. The six criteria are 1) occurrence, with those occurring most frequently ranking high, 2) arithmetic mean of the frequency of each species over all stands, 3) the ratio between the computed standard deviation of observations for that species and one predicted on the basis of the mean, 4) information content based on presence and absence, 5) the relative contributions made by each species in the calculation of interstand distance, and 6) the absolute weighing of each along the first five principal component axes. This last step results in a ranked list of species. The 56 species to be used in subsequent analysis were selected from those ranking highest on this list with one exception. In an effort to have each vegetational stratum well represented some species which fell in the middle of the master list but high when only their own stratum was considered, were included in the reduced species list. The equations for these 6 criteria are given in section E of the appendix. The species composing the "reduced species list" are underlined in the complete species list found in section A of the appendix.

4. Community Type Identification or Classification. -- The first step in the analysis was the identification of well-defined vegetation types from the older stands. This was accomplished objectively by a

^{6/} Original correspondence (1972) with Ohmann now on file at the Institute of Northern Forestry, Fairbanks.

sequency of 1) clustering and 2) ordination (Fig. 1) and subjectively by comparing stand photographs, stand age data, tree, sapling and seedling data and, when necessary, additional stand data. Data from 34 mature white spruce and black spruce stands were used in the community type identification. Stand ages ranged from 50 to 200 years.

1) Clustering: We used a polythetic agglomerative numerical classification technique based on within-group dispersion using standard distance (Orloci 1967) and frequency of species occurrence. For a more complete discussion of the method see section E of the appendix. Orloci feels that this technique, when compared to similar methods, gives the most meaningful results (ibid). This technique pairs most similar stands and/or stand groups in successive cycles. To produce a hierarchy of stand relationships. Fig. 2 is a dendrogram or pictorial representation of our findings. The number of stand groups resulting from this technique depends on the level of the hierarchy that is chosen. I selected classification levels which resulted in 14-15 stand groups. This seemed to give the best compromise between previously defined groups (Lutz '56, Viereck '73) and what I felt were distinct types. All of these stand groups except one separate at the 25% level. The two stands which unite to form this group do so at the 29% level. Even though the group is more dissimilar it was treated as one stand group type in this study because of its small size. If more stands had been visited perhaps this group would have been split. These 14 stand groups then became our tentative mature community types.

2) Canonical Analysis: The intent of this ordination technique is to establish the relationship between the stand groups or tentative community types produced from the classification (Seal 1964). This procedure is

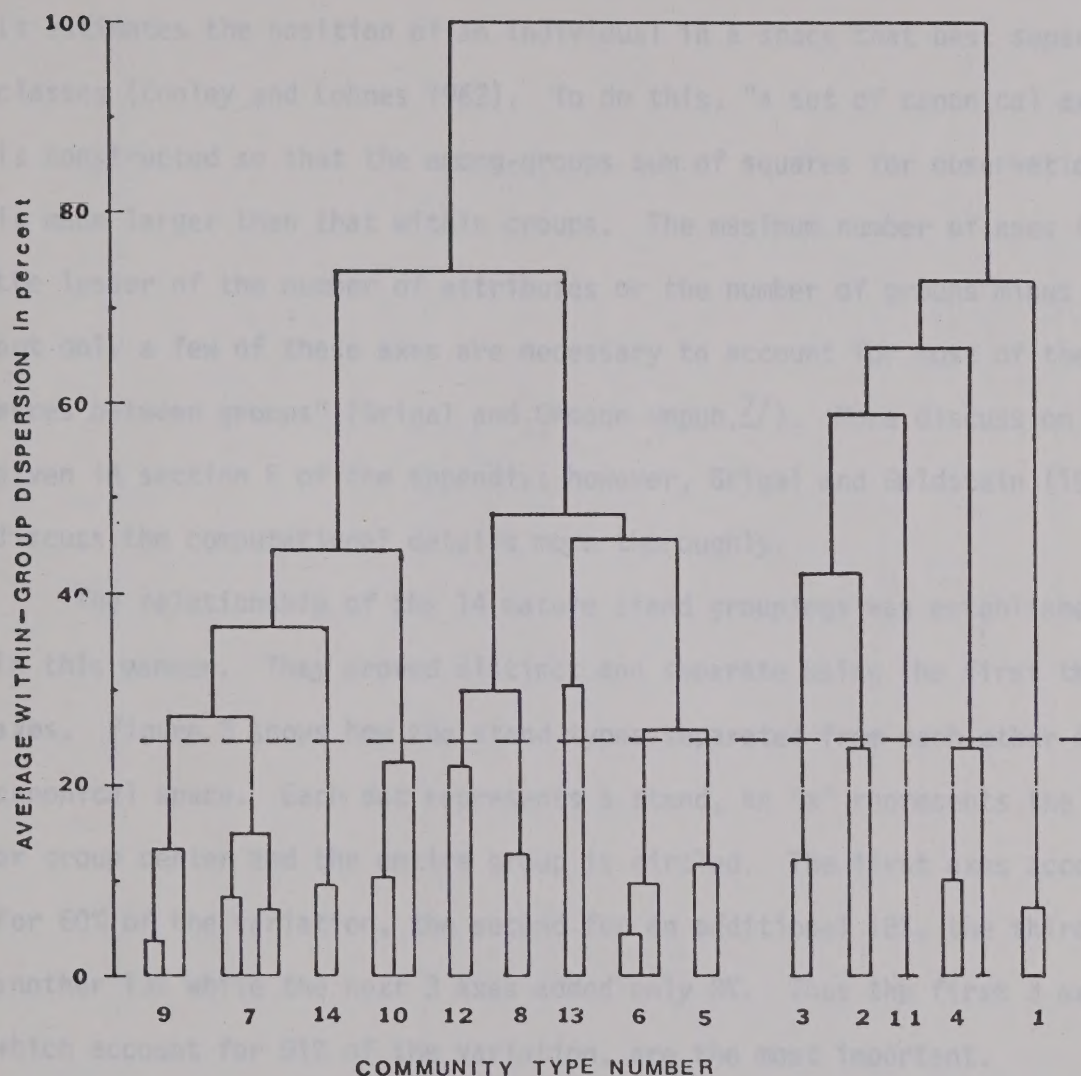


Figure 2.--Dendrogram of the stand clusters composing the 14 mature community types identified in this study. The dashed line shows the level of similarity selected to define the 14 group clusters. The community types are 1) A/VIB/T-F, 2) B/VIB, 3) WS/VIB/E.arv, 4) WS/T-F/E.syl, 5) A-BS/COR, 6) BS-A-B/CAL, 7) BS/LIC, 8) BS/R/PEL, 9) BS/L-T/E.syl, 10) BS/N-L L-T/SPH, 11) B-WS-BS/CAL, 12) BS-WS/GW/HYL, 13) BS-WS/L-T/GEO/HYL-PL, and 14) BS-WS/LIC. See text, page , for full name information.

sometimes called multiple discriminant analysis (Norris and Barkham 1970). It estimates the position of an individual in a space that best separates classes (Cooley and Lohnes 1962). To do this, "a set of canonical axes is constructed so that the among-groups sum of squares for observation is made larger than that within groups. The maximum number of axes is the lesser of the number of attributes or the number of groups minus one, but only a few of these axes are necessary to account for most of the differences between groups" (Grigal and Ohmann unpub.^{7/}). More discussion is given in section E of the appendix; however, Grigal and Goldstein (1971) discuss the computational details more thoroughly.

The relationship of the 14 mature stand groupings was established in this manner. They proved distinct and separate using the first three axes. Figure 3 shows how the stand types separated from each other in canonical space. Each dot represents a stand, an "x" represents the average or group center and the entire group is circled. The first axes accounted for 60% of the variation, the second for an additional 18%, the third for another 13% while the next 3 axes added only 8%. Thus the first 3 axes, which account for 91% of the variation, are the most important.

3) Subjective Stand Groupings: Simultaneously with the canonical analysis, the stands were subjectively grouped using stand photographs, stand ages, tree, sapling, and seedling species composition, as well as species cover and density values.

The results from the subjective and objective techniques were then compared. Some minor differences existed. After inspection the results

^{7/} Unpublished manuscript. Classification of upland communities in Minnesota on file at the Institute of Northern Forestry, Fairbanks.

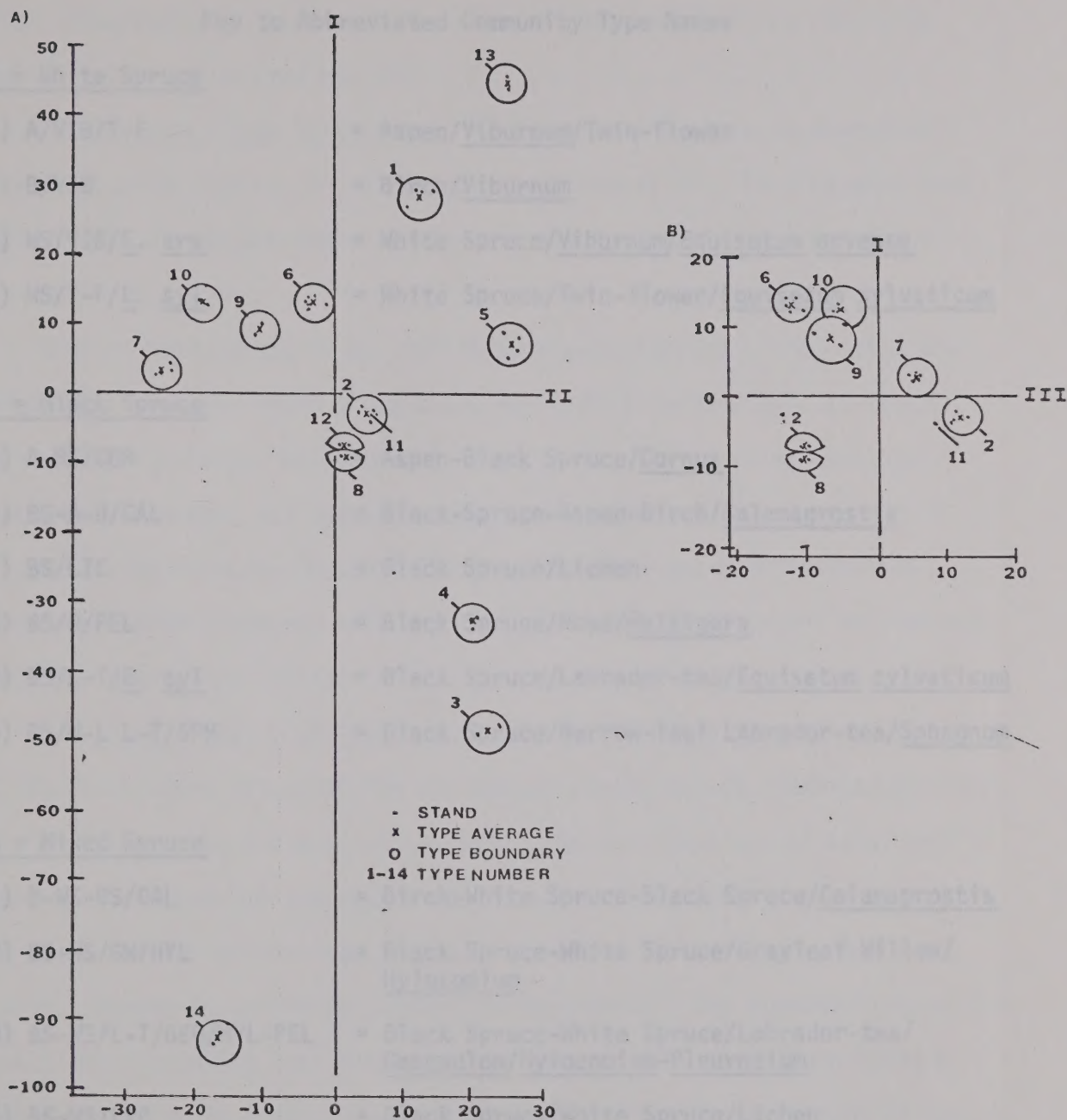


Figure 3. --Canonical ordination on 14 mature plant community types found on WS, BS, and mixed spruce sites in interior Alaska. A) Location in the plane of the first two canonical axes. These axes account for 78% of the variation. B) Separation of some groups along the first and third canonical axes. The third axes accounts for an additional 12% of the variation. Community types are 1) A/VIB/T-T, 2) B/VIB, 3) WS/VIB/E. arv., 4) WS/T-F/E. syl., 5) A-BS/COR, 6) BS-A-B/CAL, 7) BS/LIC, 8) BS/R/PEL, 9) BS/L-T/E. syl., 10) BS/N-L-T/SPH, 11) B-WS-BS/CAL, 12) BS-WS/GW/HYL, 13) BS-WS/L-T/GEO/HYL-PL, and 14) BS-WS/LIC. See the following page for full name information.

Box 85 OC-521
P.O. Box 23047
Denver, CO 80225

Key to Abbreviated Community Type Names

WS = White Spruce

- 1) A/VIB/T-F = Aspen/Viburnum/Twin-flower
- 2) B/VIB = Birch/Viburnum
- 3) WS/VIB/E. arv = White Spruce/Viburnum/Equisetum arvense
- 4) WS/T-F/E. syl = White Spruce/Twin-flower/Equisetum sylvaticum

BS = Black Spruce

- 5) A-BS/COR = Aspen-Black Spruce/Cornus
- 6) BS-A-B/CAL = Black Spruce-Aspen-Birch/Calamagrostis
- 7) BS/LIC = Black Spruce/Lichen
- 8) BS/R/PEL = Black Spruce/Rose/Peltigera
- 9) BS/L-T/E. syl = Black Spruce/Labrador-tea/Equisetum sylvaticum
- 10) BS/N-L L-T/SPH = Black Spruce/Narrow-leaf Labrador-tea/Sphagnum

MS = Mixed Spruce

- 11) B-WS-BS/CAL = Birch-White Spruce-Black Spruce/Calamagrostis
- 12) BS-WS/GW/HYL = Black Spruce-White Spruce/Grayleaf Willow/Hylocomium
- 13) BS-WS/L-T/GEO/HYL-PEL = Black Spruce-White Spruce/Labrador-tea/Geocaulon/Hylocomium-Pleurozium
- 14) BS-WS/LIC = Black Spruce/White Spruce/Lichen

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of the objectively derived groupings were adopted as the best community type we could derive from the data.

5. Community Type Description. -- The community type is described as the composite average of all stands that compose it. Thus by obtaining the average of each parameter we obtained the descriptive values listed in Tables 2 and 3.

Many of the vegetative parameters were computerized. Thus using the summarizing program CONSUM (Ohmann and Ream '71b) we were able to obtain the percent frequency, and per cent cover values for the plant species. Where the parameters had not been computerized we used a desk calculator to compute the averages (percent litter, dead wood and charred ground, stand age, depth to permafrost, and thickness of organic layer, and average number of species per stand).

6. Identification of Distinct Stages in Post-Fire Succession. -- All the techniques discussed for the mature stands except canonical analysis were applied to the successional stands. The objective use of numerical classification and the subjective use of stand photographs, stand age data and stand species composition were all important in identifying the most distinct stages in post-fire vegetation succession. The numerical classification determined the most similar stand groups. The subjective methods then assisted us in determining, 1) the level of similarity that held the most significant meaning in understanding succession, and 2) how the various stand groups related to each other.

All stands occurring on black spruce sites were treated together and all stands on white spruce sites were treated together. Those stands occurring on mixed spruce sites were sometimes treated with the black spruce

and sometimes with the white spruce depending on how they separated out in the dendrogram (Fig. 2). Because of computer program requirements, more stands were needed in the white spruce site group so the aspen-black spruce and black spruce-hardwood stands were included in this run. In both, the black spruce site and the white spruce site runs, the aspen-black spruce and black spruce-hardwood types proved distinct.

Table 1 shows the successional types that were identified in the study. Most of these types were clearly defined, however, there was some overlap, especially with the black spruce types.

7. Description of the Vegetation in each Stage of Post-Fire Succession. --

For each of the 14 stand types listed in Table 1 an average description of the percent frequency, percent cover and density per hectare of the vegetation was obtained for each years-since-burn category represented in the study. The computer program CONSUM was helpful in accomplishing this.

Although succession is a continuous process, every stand type seemed to pass through the following six distinct successional stages: 1) black ash stage (0 years), 2) seedling-sucker-herb stage (1-5 years), 3) willow shrub stage (6-25 years), 4) dense hardwood stage (26-50 years), 5) mature aspen and dense spruce stage (50-100 years), and mature birch and climax spruce stage (>100 years). To focus most clearly on these stages it seemed most expedient to describe a generalized succession story for, 1) all stand types occurring on white spruce sites, and 2) for all stand types occurring on black spruce and most stands on mixed spruce sites. The latter two were combined because they were somewhat related and the mixed spruce group was too small to stand alone.

After the general succession stages are described for a given site type, general comments are made on how each of the various stand types diverges from the general site type.

8. Identification of Woody Browse Species and a Description of Their Availability and Utilization in Each Stage of Post-Fire Succession. --Woody browse species are any woody species in which one or more stems show use by animals. (No distinction was made between browsing by animals, such as hares, which leave teeth marks on the twigs, and moose, which tend to tear the branches.) This determination was done by a visual inspection of the woody species at the shrub plots within each stand.

The availability of these species is first summarized on a stems/hectare basis from the vegetation data for those stands where browse occurs. The data from these browsed stands are then summarized 1) by species and post-burn age class for each climax site type, and 2) by tree species, willow species, and non-willow shrub categories for each climax site. Since all counts were done at ground level, all stems are treated alike; that is, no density distinction is made between short or tall, large or small diameter branches.

Utilization of the browse species is difficult to quantify. The original data are in use class units (1-33, 34-66, and 67-99% utilization) for three height classes (0-1, 1-2, and 2-3 m). To interpret these data each use class was converted to percent value by using the class mid-point as the representative value. Thus 16% represented the 1-33% class, 50% the next, and 82% the highest use class. It then became possible to average the utilization values from the 20 plots within a stand for each species and height class category. Thereafter this stand data is summarized by,

After the general succession stages are described for a given site type, general comments are made on how each of the various stand types differs from the general site type.

6. Identification of Woody Browse Species and a Description of Their

Availability and Utilization in Each Stage of Post-Fire Succession. -- Woody

Browse species are any woody species in which one or more stems show use by animals. (The distinction was made between browsing by animals, such as hares, which leave tooth marks on the twigs, and moose, which tend to tear the branches.) This determination was done by a visual inspection of the woody species at the study plots within each stand.

The availability of these species is first summarized on a stand/hectare basis from the vegetation data for those stands where browse occurs. The data from these browsed stands are then summarized 1) by species and post-fire use class for each climax site type, and 2) by tree species, within species, and non-woody shrub categories for each climax site. Since all counts were done at ground level, all stems are treated alike; that is, no density distinction is made between short or tall, large or small diameter branches.

Utilization of the browse species is difficult to quantify. The original data are in use class units (1-33, 34-66, and 67-99 utilization) for three height classes (0-1, 1-5, and 5-3 m). To interpret these data each use class was converted to percent value by using the class mid-point as the representative value. Thus 100 represented the 1-33 class, 500 the next, and 850 the highest use class. It then became possible to average the utilization values from the 30 plots within a stand for each species and height class category. Thereafter this stand data is summarized by,

1) species, height class, and post-burn age class category and, 2) height class, post-burn age class category, and tree species, willow species, and non-willow shrub species categories for each climax site type. In summarizing this information for a given species, only those stands where that species was browsed were used in the averaging. In summarizing the group categories (tree, willow, and non-willow) first, the densities on browsed stands for each species in the group were totaled for all stands within a given age class category and second, this total was divided by the total number of browsed stands found in the age-group. The species information is listed in Tables 6 and 7. The tree, willow, and non-willow shrub category information is graphed in Figures 30 and 31.

So far this discussion has considered the availability and actual utilization of the woody browse species. Do the animals show any preference? To investigate this possibility I calculated a preference index for each species. This index is calculated with the following formula:

$$PI = \frac{\text{Number of Stands Where the Species was Browsed}}{\% \text{ of Stands Where the Species Occurred}}$$

To see if there were differences between climax site types these PI values were calculated for all species occurring on 1) white spruce climax sites and 2) black spruce climax sites.

9. Description of the Potential Forest Floor Fuels in each Stage of Post-Fire Succession. -- Our analysis of the data showed that the growth form of the major tree species contributes heavily to the fuels present. The growth form of aspen and birch seemed somewhat similar so pure stands of these species were treated together. Likewise pure stands of spruce,

1) species, height class, and post-burn age class category and 2) height class, post-burn age class category, and tree species, within species, and non-willow shrub species categories for each climax site type. In summarizing this information for a given species, only those stands where that species was browsed were used in the averaging. In summarizing the group categories (tree, willow, and non-willow) first, the densities on browsed stands for each species in the group were totaled for all stands within a given age class category and second, this total was divided by the total number of browsed stands found in the age-group. The species information is listed in Tables 6 and 7. The tree, willow, and non-willow shrub category information is graphed in Figures 30 and 31.

So far this discussion has considered the availability and actual utilization of the woody browse species. Do the animals show any preference? To investigate this possibility I calculated a preference index for each species. This index is calculated with the following formula:

$$PI = \frac{\text{Number of Stands Where the Species was Browsed}}{\text{2 of Stands Where the Species Occurred}}$$

To see if there were differences between climax site types these PI values were calculated for all species occurring on 1) white spruce climax sites and 2) black spruce climax sites.

9. Description of the Potential Forest Floor Fuels in each Stage

of Post-Fire Succession. -- Our analysis of the data showed that the growth form of the major tree species contributes heavily to the fuels present. The growth form of aspen and birch seemed somewhat similar to pure stands of these species were treated together. Likewise pure stands of spruce,

either white spruce and/or black spruce, were treated as a group. Stands containing a mixture of the two types, broadleaf and conifer species, were treated as two groups; those with mostly hardwoods and those with mostly spruce. The information was then analyzed by stand, and then averaged for each age class within each of these four groups.

The slash fuel values for each stand were converted to T/ha using a metric conversion of the equations developed by Brown (1974) and then averaged. The other parameters were averaged directly from the field data for each stand. All the averaged stand data for each age-class with each of the four type categories were averaged. These values are found in Tables 8-10.

10. Description of the Soils Found on Upland Slopes in Interior Alaska. -- The analysis of the soils data is incomplete and the interpretation of the data is at best tentative. However, at this point, it seems most meaningful to divide the data into stands of most similar litter type or into the following 4 types: 1) hardwood, 2) hardwood-white spruce, 3) hardwood-black spruce, and 4) black spruce. Within each of these types the data was first averaged by stand age class groupings (0-5, 6-25, 26-50, 51-100, and 100 years). Next these 5 averaged values were again averaged to determine a grand average for the type.

IV. RESULTS AND DISCUSSION

A. Concepts of Plant Succession

Earlier in this paper, in the methods section, the concepts of climax, habitat or site type, mature community types and successional community types were introduced. In the following discussion these concepts will

either white spruce and/or black spruce, were treated as a group. Stands containing a mixture of the two types, broadleaf and conifer species, were treated as two groups; those with mostly hardwoods and those with mostly spruce. The information was then analyzed by stand, and then averaged for each age class within each of these four groups.

The slash fuel values for each stand were converted to T/h using a metric conversion of the equations developed by Brown (1974) and then averaged. The other parameters were averaged directly from the field data for each stand. All the averaged stand data for each age-class with each of the four type categories were averaged. These values are found in Tables 8-10.

10. Description of the Data Found on Upland Slopes in Interior Alaska.

The analysis of the data is incomplete and the interpretation of the data is at best tentative. However, at this point, it seems most meaningful to divide the data into stands of most similar forest type or into the following 4 types: 1) hardwood, 2) hardwood-white spruce, 3) hardwood-black spruce, and 4) black spruce. Within each of these types the data was first averaged by stand age class groupings (0-5, 6-25, 26-50, 51-100, and 100 years). Next these 5 averaged values were again averaged to determine a grand average for the type.

IV. RESULTS AND DISCUSSION.

A. Concepts of Plant Succession

Earlier in this paper, in the methods section, the concepts of climax, habitat or site type, mature community types and successional community types were introduced. In the following discussion these concepts will

be expanded.

1. Climax Habitat or Site Type. -- This ecological concept is defined by Odum as "the final or stable community in a successional series; it is self-perpetuating and in equilibrium with the physical habitat"(Odum 1959).

It infers that disturbances like fire, floods, and timber harvesting do not occur. One might ask then, what use is this concept in interior Alaska where disturbance is a part of the scene? Even though few areas ever reach this climax stage it is a useful concept with which to order the vegetation types that do occur. Within fifty to sixty years following a fire the vegetation within a stand has become sufficiently mature to be able to characterize it as to site type. Since most of the older forested areas have trees with age ranging from 50-150 years the site type can be inferred.

The four main climax types are 1) white spruce, 2) upland black spruce, 3) lowland black spruce - bog and 4) mixed black spruce-white spruce. Each of these will be discussed.

1) White Spruce Climax Type: This type may be found on upland slopes or river bottom terraces throughout the Alaskan interior where it is warm, dry and the soil well-drained. These sites may occur from near sea level to timberline elevations, which vary from 305-1,607 m (1,000-3,500 ft)(Viereck and Little 1972) depending on latitude and longitude. Most of the upland slopes have a gradient of less than 22% and a southerly exposure (Table 2). The soil on many of these sites is loess which is fine wind-blown silt. The active layer (region of seasonal thaw) is thick. By late June the thaw reaches a minimum depth of 49 cm and by early August it disappears entirely or retreats to a depth greater than 90 cm (35 in).

I. Climax Habitat or Site Type. -- This ecological concept is defined

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1) White Spruce Climax Type: This type may be found on upland slopes or river bottom terraces throughout the Alaskan interior where it is warm, dry and the soil well-drained. These sites are near sea level to timberline elevations, which vary from 305-1,507 m (1,000-4,950 ft) (Viereck and Little 1972) depending on latitude and longitude. Most of the upland slopes have a gradient of less than 35% and a southerly exposure (Tadja 1972). The soil on many of these sites is loess which is fine wind-blown silt. The active layer (region of seasonal thaw) is thick. By late June the thaw reaches a minimum depth of 40 cm and by early August it disappears entirely or retreats to a depth greater than 90 cm (36 in).

Table 2. Site parameters of 14 mature community types occurring in interior Alaska.

Climax Type - Community Type	Active Layer (Aver min depth in cm)		Slope			Organic Layer Aver Thickness in cm
	Late June	Early July	Exposure	Position	Gradient	
WS - 1) A/VIB/T-F ^{1/}	80- >90	>120	S	MS,US,RT ^{3/}	7-19	7
WS - 2) B/VIB	50- >90	> 90	S,SE	MS	7-13	13
WS - 3) WS/VIB/E. <u>arv</u>	40	> 90	SW	MS	11-22	12
WS - 4) WS/T-F/ <u>Equ</u>	27	> 90	--	V	0	8
WS Site Average	49	>100	E,SE,S,SW	V,MS,US,RT	0-22	10
BS - 5) A-BS/COR	60- >90	63- >90	S,SE,SW	V,MS	0-15	8
BS - 6) BS-A-B/CAL	48	56- >90	S,SE,NW	MS,US	3-21	16
BS - 7) BS/LIC	38 ^{2/}	60- >120	S,SE,NE,W,--	V,MS,US,RT	0-15	16
BS - 8) BS/R/PEL	E 38 ^{2/}	56- >90	E,--	LS	0- 3	15
BS - 9) BS/L-T/E. <u>sy1</u>	31	42-60	SE,E,W,NW	LS,MS,US	5-20	23
BS -10) BS/N-L L-T/ <u>SPH</u>	30	60	NW,N,--	V,LS,US	0-19	40- >120
BS Site Average	41	56-(>90)	All N,E,S,W	All V-RT	0-21	20
M -11) B-WS-BS/CAL	31	E 50 ^{2/}	SE	US	26	13
M -12) BS-WS/GW/HYL	19	54	S	LS	0- 3	18
M -13) BS-WS/L-T/GEO/HYL-PLE	E 19 ^{2/}	40	--	V	0	16
M -14) BS-WS/LIC	too rocky	too rocky	E,NE	US	15-20	0-3
M Site Average	23	48	NE,E,SE,S	V,LS,US	0-26	12

FOOTNOTES:

1/ Community type names are abbreviated. Refer to the following page for their full names.

2/ E = Estimated Value

3/ MS = Middle Slope, US = Upper Slope, RT = Ridge Top, V = Valley, LS = Lower Slope

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- 14) BS/WS = Black Spruce/White Spruce

The river bottom white spruce sites are somewhat cooler but sufficiently close to the river and underlain by enough gravel to be sufficiently dry and well-drained to maintain themselves as white spruce. The oldest white spruce stand, which was 270 years old, was located on an island of the Tanana River, where it was protected from both fire and logging.

2) Upland Black Spruce Climax Type: This type may be located on river bottom sites or on upland slopes in interior Alaska up to an elevation of 610 m (2,000 ft) (Viereck and Little 1972) or even up to 975 m (3,200 ft) on gentle timberline slopes. However, in contrast to the white spruce sites the black spruce sites are cooler and usually more moist. Seasonal frost retreats more slowly and permafrost frequently exists (see Table 2). By late June some sites have thawed only 30 cm (12 in), while the average for all black spruce sites surveyed was 44 cm (17 in). Even in August the active layer extends to an average minimum depth of 56 cm (22 in) and in the warmer locations to 120 cm (47 in). Black spruce occurs on all slope aspects, slope positions, and slope gradients found below timberline. Sometimes the sites appear well-drained; other times they are wet. This wetness can be due to the moss and organic layers retaining precipitation or to surface and soil water which is trapped in place by permafrost. The oldest black spruce stand found was between 150 and 200 years, and was located on the river bottom lands but some distance back from the Tanana River. Because of the high frequency of fires in this site type, most of the black spruce stands are less than 100 years in age.

3) Black Spruce-Bog Cyclic Climax Type: This type, which is sometimes referred to as muskeg, occurs on cool lowland and in upland valleys where drainage is poor. It is a mosaic of forested areas, open bog ponds, closed

The river bottom white spruce sites are somewhat cooler but sufficiently

close to the river and underlain by enough gravel to be sufficiently dry and well-drained to maintain themselves as white spruce. The oldest white spruce stand, which was 250 years old, was located on an island of the Tanana River, where it was protected from both fire and logging.

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bottom sites or on upland slopes in Interior Alaska up to an elevation of 610 m (2,000 ft) (Vivack and Little 1972) or even up to 975 m (3,200 ft) on gentle timberline slopes. However, in contrast to the white spruce sites the black spruce sites are cooler and usually more moist. Seasonal frost retreats more slowly and permafrost frequently exists (see Table 2). By late June some sites have thawed only 30 cm (12 in.), while the average for all black spruce sites surveyed was 44 cm (17 in.). Even in August the active layer extends to an average minimum depth of 56 cm (22 in.) and in the warmer locations to 120 cm (47 in.). Black spruce occurs on all slope aspects, along positions, and slope gradients found below timberline. Sometimes the sites appear well-drained, other times they are wet. This wetness can be due to the moss and organic layers retaining precipitation or to surface and soil water which is trapped in place by permafrost. The oldest black spruce stand found was between 150 and 200 years, and was located on the river bottom islands but some distance back from the Tanana River. Because of the high frequency of fires in this site type, most of the black spruce stands are less than 100 years in age.

3) Black Spruce-Bog Cyclic Climax Type: This type, which is sometimes

referred to as muskeg, occurs on cool lowland and in upland valleys where drainage is poor. It is a mosaic of forested areas, open bog ponds, closed

or covered bog ponds, and small thaw ponds. The soil in the forested areas and under the ponds is mostly peat. However, sometimes silt is also present. This peat layer may be several feet thick or it may be several hundred feet thick. Péwé calls this soil "organic-rich fetid perennially frozen muck" (Péwé 1968).

Any given area, over the duration of several hundred years, will be both a black spruce forest and a bog in a cyclic manner. That is, the margins of the thaw ponds continually invade the forest degrading the latter into a bog. Simultaneously silt deposition, peat deposition, and the formation of ever thickening mats of vegetation continually uplift parts of the bog, to enableing them to become reforested.

Permafrost is present. The depth of the active layer is influenced by the height of the water table, the water movement within the water table, and the effectiveness of the vegetation in insulating the soil from the summer air temperatures.

Most of the time these areas are too wet to carry a fire, but this type will burn if conditions are sufficiently dry.

4) Mixed White Spruce-Black Spruce Climax Type: This intermediate type occurs wherever the white spruce site type and black spruce site types overlap. This occurs most frequently on the lower slopes between the white spruce stands with southerly aspects and the valley bottom black spruce muskeg; but it can also occur near timberline where the cooler slopes meet the warmer ridgetops or anywhere where stands of the two species occur in close proximity.

The soils vary from the thin, stony soils which occur on many ridgetops, to a moderately thick silty peat which occurs at the foot of the south-

or covered bog ponds, and small, thin ponds. The soil in the forested areas and under the ponds is mostly peat. However, sometimes silt is also present.

This peat layer may be several feet thick or it may be several hundred feet thick. Peat cells with organic-rich cells partially frozen much (Pewé 1955).

Big open areas, over the duration of several hundred years, will be

both a black spruce forest and a bog in a cyclic manner. That is, the merging of the thin ponds continuously invades the forest degrading the latter into a bog. Simultaneously silt deposition, peat deposition, and the formation of ever thickening mats of vegetation continuously uplift parts of the bog, so enabling them to become reforested.

Permafrost is present. The depth of the active layer is influenced by the height of the water table, the water movement within the water table, and the effectiveness of the vegetation in insulating the soil from the summer air temperatures.

Most of the time these areas are too wet to carry a fire, but this

type will burn if conditions are sufficiently dry.

4) Mixed White Spruce-Black Spruce-Tamarix Type: This intermediate

type occurs wherever the white spruce type and black spruce type types overlap. This occurs most frequently on the lower slopes between the white spruce stands with southerly aspects and the valley bottom black spruce muskeg; but it can also occur near timberline where the cooler slopes meet the warmer ridges or anywhere where stands of the two species occur in close proximity.

The soils vary from thin, stony soils which occur on many ridges,

to a moderately thick silty peat which occurs at the foot of the south-

facing slopes. The presence of permafrost is also variable; some sites will have a very deep active layer and others will have a very shallow active layer.

Stands with trees 150 to 176 years old are relatively easy to find in these locations. These older stands help to characterize the variation that may occur within the black spruce climax type.

Odum, as stated earlier, defined climax type as, "the final or stable community in a successional series," which "is self perpetuating and in equilibrium with the physical habitat." What do we mean by "succession?" Odum defines it as, "the orderly process of community change; it is the sequence of communities which replace one another in a given area. Typically, community development begins with pioneer stages which are replaced by a series of more mature communities until a relatively stable community is evolved ..." (Odum '59). Commonly, in interior Alaska at least, several different successional series may end with the same climax type. This then leads to the concepts of mature community and successional community types.

2. Mature Community Types: In terms of the successional series these are the older, more stable community types. In theory at least, the oldest or most mature types are, in fact, the climax types. In practice however, there are many slightly younger community types which are able to retain their identity for 40-100 years. In interior Alaska where natural disturbance occurs continually most stands have no chance to mature for longer periods than 100-150 years. These younger semi-stable stands become the disclimax type. In this paper I have used the term mature community type to include the stable and semi-stable types, climax and the disclimax, or, in other words, any community type which can retain its self-identity

facting slopes. The presence of permafrost is also variable; some sites will have a very deep active layer and others will have a very shallow active layer.

Stands with trees 100 to 150 years old are relatively easy to find in these locations. These older stands help to characterize the variation that may occur within the black spruce climax type.

Odum, as stated earlier, defined climax type as "the final or stable community in a successional series," which "is self-perpetuating and in equilibrium with the physical habitat." What do we mean by "succession"? Odum defines it as "the orderly process of community change. It is the sequence of communities which replace one another in a given area. Typically, community development begins with pioneer stages which are replaced by a series of more mature communities until a relatively stable community is evolved..." (Odum 1961). Community, in Interior Alaska at least, several different successional series may end with the same climax type. This then leads to the concept of mature community and successional community types.

5. Mature Community Types: In terms of the successional series these are the older, more stable community types. In theory at least, the oldest or most mature types are, in fact, the climax types. In practice however, there are many slightly younger community types which are able to retain their identity for 50-100 years. In Interior Alaska where natural disturbance occurs continually most stands have no chance to mature for longer periods than 100-150 years. These younger semi-stable stands become the climax type. In this paper I have used the term mature community type to include the stable and semi-stable types, climax and the disclimax, or, in other words, any community type which can retain its self-identity

for more than 40 years, most for 100-150 years. These mature types are all more than 50 years old. After fifty years of succession following the fire, most of these stands have become sufficiently mature to characterize the site type to which it is headed.

In the analysis of our data the following 14 community types were identified from stands of 50 years of age or older.

Types occurring on white spruce sites -

- 1 - Aspen/Viburnum/Twin-flower
- 2 - Birch/Viburnum
- 3 - White Spruce/Viburnum/Equisetum arvense
- 4 - White Spruce/Twin-flower/Equisetum sylvaticum

Types occurring on black spruce sites -

- 5 - Aspen-Black Spruce/Cornus
- 6 - Black Spruce-Aspen-Birch/Calamagrostis
- 7 - Black Spruce/Lichen
- 8 - Black Spruce/Rose/Peltigera
- 9 - Black Spruce/Labrador-tea/Equisetum sylvaticum
- 10 - Black Spruce/Narrow-leaf Labrador-tea/Sphagnum

Types occurring on mixed black and white spruce sites -

- 11 - Birch-White Spruce-Black Spruce/Calamagrostis
- 12 - Black Spruce-White Spruce/Grayleaf Willow/Hylocomium
- 13 - Black Spruce-White Spruce/Labrador-tea/Geocaulon/Hylocomium-
Pleurozium

- 14 - Black Spruce-White Spruce/Lichens

Each of these community types will be described later in the paper.

3. Successional Community Type: In contrast to the mature community types the successional community types are community types that appear in any successional series. They include the community types occurring in younger pioneering stages and the more mature stages as well. In most successional series in interior Alaska at least 6 successional community types will be encountered. Each of these will be defined and described later in this report.

B. Mature Community Types Occurring on

Upland Sites in Interior Alaska

At this time each of the 14 community types identified in this study will be discussed by site type and in the order they were listed on page 10. Those occurring on white spruce sites will be described first; they will be followed by those found on black spruce sites and by those on mixed spruce sites.

1. White Spruce Sites. -- The following four mature community types were identified as occurring within the white spruce climax type: 1) Aspen/ Viburnum/Twin-flower, 2) Birch/Viburnum, 3) White Spruce/Viburnum/Equisetum arvense, and 4) White Spruce/Twin-flower/Equisetum sylvaticum. The aspen type is the least stable and shortest lived. It can retain its identity as a mature type for about 40 years. After that it changes into either a birch or a white spruce type. Type two, the birch type, on the other hand, can retain its identity for 100-150 years, after which it usually changes into a white spruce type or a mixed spruce type. Types 3 and 4, the white spruce types, can retain their identity until destroyed by disturbance.

A look at Figure 3, which shows how the mature types stand out in

canonical space, shows that these white spruce types (types 1-4) are distinct. The only type that overlaps in any way is type 11, the Birch-White Spruce-Black Spruce/Calamagrostis type which is certainly related to the Birch/ Viburnum type.

In the following discussion each of these types will be discussed.

1) Aspen/Viburnum/Twin-flower: This community type, which is pictured in Figure 4, occupies the warmest white spruce sites studied and is best developed in 50-60-year-old stands. It is both common and extensive. Ground frost, for the most part disappears in June (Table 2). The type occurs mostly on slopes that are south-facing and with a gradient of 7-19% and it can be found on ridgetops, upper slope and middle slope positions. The average thickness of the organic layer is only 7 cm (3 in).

The flora in the aspen/Viburnum/twin-flower community is moderately diverse, averaging 35 species per stand. The average density of all tree species totals 1,525 trees, 5 sapling trees, and 117,114 seedling and root shoots per hectare; while the average density of all willow species totals 1,000/ha, and the average density of all non-willow tall shrub species totals 56,874/ha. The average percent cover for low shrubs totals 16.0, for herbs totals 28.2, for mosses totals 2.0, and for lichens totals .8.

By definition this type is dominated by Populus tremuloides, Michx. (quaking aspen). These trees average over 1,000 per hectare. In sixty year old stands the trees will have an average diameter at breast height (dbh) of 14.6 cm (5.8 in)(Table 3). Other tree species may be present, usually as an understory, but occasionally as a relic from an earlier preburned stand. Slowly, as the overstory aspen die, these understory



Figure 4.--Aspen/Viburnum/twin-flower community type occurring on climax white spruce sites in interior Alaska. The trees in this stand (136) are 70 years in age.

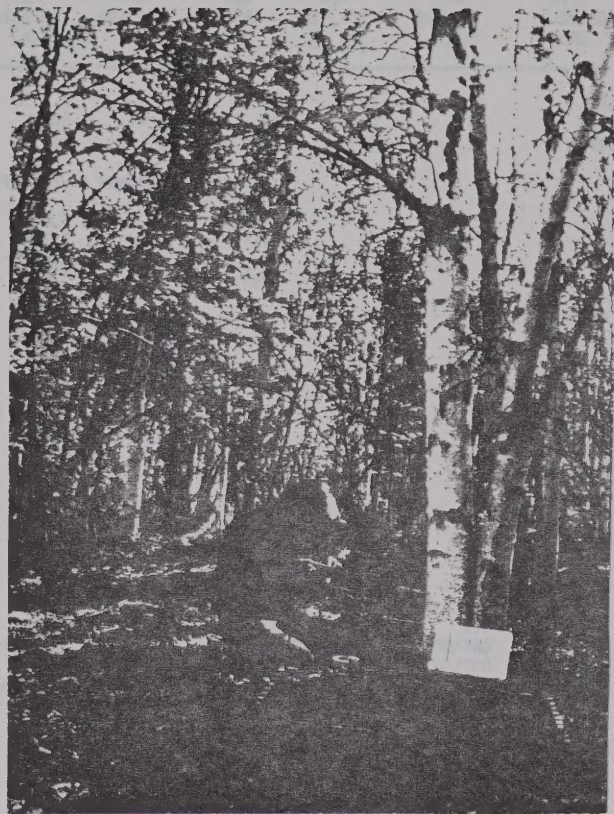


Figure 5.--Birch/Viburnum community type occurring on climax white spruce sites in interior Alaska. The birch trees in this stand (135) are 55 years in age.

Table 3. Description of 14 plant community types found on white spruce, black spruce, or mixed spruce climax sites in interior Alaska.

Climax Type	White Spruce				Black Spruce						Mixed Spruce			
	-1- A/VIB/ T-F	-2- B/VIB	-3- WS/VIB/ E. arv	-4- WS/T-F/ EQU	-5- A-BS/ COR	-6- BS-A-B/ CAL	-7- BS/LIC	-8- BS/R/ PEL	-9- BS/L-T/ E. syl	-10- BS/N-L L-T/SPH	-11- B-WS-BS /CAL	-12- BS-WS/ GW/HYL	-13- BS-WS/ L-T/GEO /HYL-PLE	-14- BS-WS/ LICH
Community Type 1/														
Number of Stands	2	2	2	3	2	3	4	2	3	3	1	2	2	2
Average Age (years)	57	120	150	180	75	80	60	90	60	110	125	125	175	60(150)
Average Number Species/Stand	35	27	37	28	40	32	37	36	38	35	26	46	39	46
TREE SPECIES -	(Average tree diameter (in cm), % frequency (F), and density (D) as number per hectare.)													
<u>Populus tremuloides</u>														
tree diameter (dbh)	14.6		34.0		12.9	13.0		23.9						
tree F/D	100/1,371		8/14		95/1,453	13/254		5/24						
sapling F/D			2/.3		3/.5	8/12								
seedling F/D	25/2,562		12/1,125		35/2,667	3/83		2/62						.4/12
<u>Betula papyrifera</u>														
tree diameter (dbh)	9.0	27.4	20.4	12.2	9.3	16.1	6.8				14.9	10.9		5.0
tree F/D	22/107	100/622	25/38	37/109	20/156	12/114	5/53				100/744	2/29		5/5
sapling F/D	2/5	30/7	32/6	7/5	12/2	3/10	1/6		2/3	3/.4	10/2			10/2
seedling F/D	28/113,938		10/750		3/208	2/42	1/62							
<u>Picea glauca</u>														
tree diameter (dbh)	10.5	25.6	26.0	24.6	11.0	13.8	19.9				20.6	5.0	16.7	8.9
tree F/D	5/19	52/113	100/496	98/581	3/26	3/23	1/27				35/83	15/165	8/29	4/5
sapling F/D		35/6	52/20	2/2	8/2	3/10	1/5				80/32	18/9		78/51
seedling F/D	8/312		25/1,625	22/1,208	10/875						10/1,875	2/62		2/50
seedling (Picea species) F/D												10/250		
<u>Populus balsamifera</u>														
tree diameter (dbh)	ND			27.0								16.4	ND	ND
tree F/D	5/18			3/9								5/58	18/175	62/139
sapling F/D			18/3											3/85
seedling F/D	5/312													
<u>Picea mariana</u>														
tree diameter (dbh)	13.2				5.8	9.8	4.9	6.2	7.2	6.2		6.2	11.7	7.8
tree F/D	2/10				60/451	92/1,717	99/2,613	100/210	100/1,682	100/760		100/3,582	98/1,772	90/259
sapling F/D					90/36	98/796	100/2,273	95/58	100/1,115	100/290	60/19	90/452	5/5	98/77
seedling F/D					47/6,625	72/10,167	92/15,562	75/14,312	95/20,250	82/8,875		75/10,000	10/438	54/7,000

Table 3 continued

Climax Type	White Spruce				Black Spruce						Mixed Spruce			
	-1- A/VIB/ T-F	-2- B/VIB	-3- WS/VIB/ E. arv	-4- WS/T-F/ EQU	-5- A-BS/ COR	-6- BS-A-B/ CAL	-7- BS/LIC	-8- BS/R/ PEL	-9- BS/L-T/ E. syl	-10- BS/N-L L-T/SPH	-11- B-WS-BS /CAL	-12- BS-WS/ GW/HYL	-13- BS-WS/ L-T/GEO /HYL-PL	-14- BS-WS/ LICH
Community Type														
Tree Species continued -														
<u>Larix laricina</u>														
tree diameter (dbh)										ND			ND	
tree F/D										7/11			2/15	
sapling F/D							1/6			7/14				
seedling F/D														
Total Tree Density	1,525	735	548	699	2,086	2,108	2,693	234	1,682	771	827	3,834	1,991	408
Total Sapling Density	5	13	29.3	7	40.5	828	2,290	58	1,118	304	51	461	5	130
Total Seedling Density	117,124	0	3,500	1,208	10,375	10,292	15,624	14,374	20,250	8,875	1,875	10,312	438	7,150
TALL SHRUB SPECIES -	(% frequency (F) and density (D) in stems per hectare)													
Willow:														
<u>Salix babingtoniana</u>	F/D	18/1,000			7/333		4/94	32/2,062						
<u>Salix scouleriana</u>						1/31	5/594							
<u>Salix alaxensis</u>							2/62							
<u>Salix glauca</u>								2/125				32/2,000	2/312	
<u>Salix pulchra</u>									18/1,000					5/158
<u>Salix arbusculoides</u>												25/1,438	2/62	
<u>Salix species</u>							1/94					5/125	2/62	38/3,750
Total Willow Density	1,000	0	0	0	333	31	844	2,187	1,000	0	0	3,563	436	3,638
Non-Willow:														
<u>Rosa acicularis</u>		88/18,562	95/18,250	70/12,312	87/19,292	35/3,000	18/1,969	10/344	92/4,438	7/292	5/125	25/625	50/2,188	32/1,562
<u>Viburnum edule</u>		80/36,750	75/20,562	40/7,562	27/1,750	3/125						3/1,125	2/62	
<u>Alnus crispa</u>		5/1,562	22/2,250	5/188	7/3,000	10/3,333	28/2,031	2/125		7/417	40/3,625		40/8,125	
<u>Alnus tenuifolia</u>					8/458									
<u>Betula glandulosa</u>									43/7,417					72/19,812
Total Non-Willow Tall Shrub Density	56,874	41,062	20,062	24,500	6,458	4,000	469	4,438	8,126	0	3,750	1,750	10,375	21,374

Table 3 continued

Community Type	White Spruce				Black Spruce						Mixed Spruce			
	-1- A/VIB/ T-F	-2- B/VIB	-3- WS/VIB/ E. arv	-4- WS/T-F/ EQU	-5- A-BS/ COR	-6- BS-A-B/ CAL	-7- BS/LIC	-8- BS/R/ PEL	-9- BS/L-T/ E. syl	-10- BS/N-L L-T/SPH	-11- B-WS-BS /CAL	-12- BS-WS/ GW/HYL	-13- BS-WS/ L-T/GEO /HYL-PL	-14- BS-WS/ LICH
LOW SHRUB SPECIES -	(% frequency (F) and % cover (C))													
<i>Linnaea borealis</i> F/C	82/13	48/.5	15/1	85/8	12/1			2/.03			10/.2	12/.1	15/.4	
<i>Vaccinium vitis-idaea</i>	38/3			45/6	73/11	95/9	100/12	98/5	98/20	98/9	35/3	85/11	100/17	100/24
<i>Ledum arcticum</i>	2/.02			3/.03	18/1	8/1	43/7	35/1	95/11	33/2		10/.4	65/6	65/5
<i>Picea canadensis</i>		25/3	8/1	7/.1	2/1					2/.02				
<i>Salix bebbiana</i>				13/1	2/.02	2/.02	9/.2	2/.1	7/.4	8/.2				8/.1
<i>Vaccinium uliginosum</i>					52/3	47/3	64/5	85/1	95/8	95/6		15/1	22/1	98/23
<i>Arctostaphylos uva-ursi</i>					2/.03							2/.03		
<i>Empetrum nigrum</i>						3/.4	6/.2	5/.4	12/1	67/6		48/2	25/3	42/4
<i>Ledum palustre</i>						2/.03	4/.2		57/3	98/10		2/.03		10/.3
<i>Vaccinium oxycoccus</i>							1/.01		37/1	55/2				2/.03
<i>Salix species</i>								25/.1						
<i>Ledum species</i>									2/.2					
<i>Betula nana</i>										75/5			5/.05	
<i>Chamaenerion caliculata</i>										13/1				
<i>Arctostaphylos rubra</i>												42/3	20/1	5/.3
<i>Arvas integrifolia</i>												15/1		
<i>Potentilla fruticosa</i>												10/.1		
Total Low Shrub Cover	16.02	3.5	2.0	15.13	17.05	13.45	24.61	7.63	44.6	41.22	3.2	18.66	28.45	56.73
HERB SPECIES -	(% frequency (F), and % cover (C))													
<i>Equisetum arvense</i> F/C	92/14	42/18	82/4	58/5	2/.02		29/.3	5/.05				20/.4	12/.2	
<i>Cornus canadensis</i>	85/8	72/2	2/.02	45/1	98/6	20/1	32/.3	38/.4			5/.05	15/.2	5/.1	10/.1
<i>Epilobium angustifolium</i>	78/2	28/1	25/.2	2/.02	20/.4						5/.05			
<i>Galium aparine</i>	55/1	40/2	32/1	23/.5	60/1	85/6	52/1	68/1	63/1		90/5	72/3	85/5	58/2
<i>Pedicularis lateriflora</i>	30/.3	32/.4	22/.2											
<i>Verticillium paniculata</i>	20/.3		28/1	5/.05	8/.1			32/.1				12/.2		15/.2
<i>Pyrola secunda</i>	15/.3	2/.02	18/.5	23/.4	3/.03			5/.05	2/.02			15/.2	15/.1	
<i>Pedicularis labradorica</i>	12/.2				2/.02									

Table 3 continued

	White Spruce				Black Spruce						Mixed Spruce			
	-1- A/VIB/ T-F	-2- B/VIB	-3- WS/VIB/ E. arv	-4- WS-T-F/ EQU	-5- A-BS/ COR	-6- BS-A-B/ CAL	-7- BS/LIC	-8- BS/R/ PEL	-9- BS/L-T/ E. syl	-10- BS/N-L L-T/SPH	-11- B-WS-BS /CAL	-12- BS-WS/ GW/HYL	-13- BS-WS/ L-T/GEO /HYL-PLE	-14- BS-WS/ LICH
Community Type														
Herb Species continued -														
<i>Epilobium</i> species	10/1													
<i>Pyrola asarifolia</i>	10/.4	8/.4	2/.1	25/1										
<i>Geocaulon lividum</i>	10/.3		55/4	45/1	15/.4	50/2	48/1		23/.5			10/.1	80/5	5/.1
<i>Pyrola grandiflora</i>	10/.2			2/.02										
<i>Lycopodium complanatum</i>	5/.4					3/.03					5/.1			2/.1
<i>Plantago</i> species	5/.1											12/.2		
<i>Pyrola</i> species	2/.02			2/.03				8/.1				32/1	22/1	
<i>Scirpus pratense</i>		50/8												
<i>Scirpus sylvaticum</i>		8/.3		33/7			2/.04	2/.03	73/4	2/.1			52/4	
<i>Galium boreale</i>		2/1	40/.4		6/.1								2/.03	
<i>Androsace medeolifolia</i>		2/.02	2/.02										2/.03	
<i>Androsace polifolia</i>		2/.02			2/.02									
<i>Pyrola chlorantha</i>			20/.2											
<i>Deschampsia cespitosa</i>			12/.2											
<i>Deschampsia cespitosa</i>			2/.2	10/.1	2/.02								5/.05	
<i>Carex</i> species				12/.2										
Herbaceous Unknown				3/.05			1/.2							
<i>Scirpus</i> species				2/.02					5/.05				2/.05	22/1
<i>Scirpus</i> species				2/.02										
<i>Scirpus</i> species					7/.4	18/1	20/.4		2/.02		40/2			20/.3
<i>Scirpus</i> species					5/.03			2/.03						
<i>Scirpus</i> species						2/.05		12/.2	7/.4			52/16	42/2	12/.3
<i>Betula glandulosa</i>							11/.2		87/6	98/7		2/.03	2/.05	
<i>Betula glandulosa</i>							6/.1	5/.2	20/.4	2/.1		10/.3		12/.2
<i>Lycopodium clavatum</i>							6/.1							
<i>Polygonum alaskanum</i>							1/.01		12/.3					
<i>Lupinus arcticus</i>														
<i>Lotus rupestris</i>								28/1						
<i>Erigeron vaginatus</i>								2/.2						
<i>Carex</i> species									3/.03	23/2		2/.1		10/.1
<i>Drosera rotundifolia</i>										80/12		28/1	8/.2	18/.3
<i>Polygonum bistorta</i>										5/.1				
										2/.03				

Table 3 continued

Community Type	White Spruce				Black Spruce						Mixed Spruce			
	-1- A/VIB/ T-F	-2- B/VIB	-3- WS/VIB/ <u>E. arv</u>	-4- WS/T-F/ EQU	-5- A-BS/ COR	-6- BS-A-B/ CAL	-7- BS/LIC	-8- BS/R/ PEL	-9- BS/L-T/ <u>E. syl</u>	-10- BS/N-L L-T/SPH	-11- B-WS-BS /CAL	-12- BS-WS/ GW/HYL	-13- BS-WS/ L-T/GEO /HYL-PLE	-14- BS-WS/ LICH
Herb Species continued -														
<u>Pinguicula vulgaris</u>										2/.02				
<u>Saussurea angustifolium</u>												2/.05	5/.05	
<u>Valeriana capitata</u>												8/.1		
<u>Carex arctica</u>													2/.05	
<u>Trifolium species</u>													2/.03	
Total Herb Cover	28.52	33.16	12.04	16.41	8.54	10.08	3.65	3.36	12.72	22.35	7.2	22.88	17.94	4.7
MOSS AND LIVERWORT SPECIES -	(% frequency (F) and % cover (C))													
<u>Pleurozium schreberi</u> F/C	52/1	30/2	25/5	42/8	45/4	95/47	98/45	38/16	87/30	72/23	10/.1	15/1	55/27	70/23
<u>Moss unknown</u>	18/.2			37/3	15/.3	20/.5	4/.1		5/1	5/.05	45/1	38/7	10/.2	25/.5
<u>Deschampsia cespitosa</u>	15/.4	12/1	5/.2	2/.02	40/1		35/1	2/.03		7/.1	35/1	5/.1	30/1	
<u>Deschampsia cespitosa</u>	5/.2	12/1	88/62	92/60	45/5	65/14	65/15	85/54	60/17	5/1	35/2	95/64	90/43	55/12
<u>Leafy Liverwort species</u>	5/.1				2/.02		9/.1			22/.5		40/7	20/1	2/.03
<u>Polypodium species</u>	5/.05	2/.02	5/.05	12/2	17/.2	38/1	76/6	20/.4	80/5	77/9	20/2	2/.03	2/.03	90/5
<u>Ceratodon purpurea</u>	2/.02	2/.05	5/.05				1/.04	5/.3	3/.1					12/.3
<u>Dicranum species</u>		5/.05	5/.05	7/.2	5/.1	35/1	68/3	28/1	25/1	35/2		18/.3	10/.2	50/6
<u>Utricularia species</u>		2/.02		2/.02								8/.5	2/.03	
<u>Ptilium crista-castrensis</u>			2/.02	15/3	7/.2	20/1	1/.01	5/.05	7/1				22/2	
<u>Phytidadelphus species</u>				8/1										2/.2
<u>Hylocomium species</u>				3/.3										40/3
<u>Hylocomium palustre</u>					3/.03		12/.5	2/1	48/8	8/.2	5/.05	38/7	12/1	5/2
<u>Hylocomium species</u>							11/1		73/27	85/47				
<u>Autocodium turgidum</u>							5/.1	5/.1	2/.05			8/.4		
<u>Brachythecium salebrosum</u>													8/.4	
<u>Eurhynchium species</u>													8/.2	
Total Moss Cover	1.97	6.14	67.37	77.54	10.85	64.5	71.85	72.88	90.15	82.85	6.15	87.33	76.06	52.03

Table 3 continued

Community Type	White Spruce				Black Spruce						Mixed Spruce			
	-1- A/VIB/ T-F	-2- B/VIB	-3- WS/VIB/ E. arv	-4- WS/T-F/ EQU	-5- A-BS/ COR	-6- BS-A-B/ CAL	-7- BS/LIC	-8- BS/R/ PEL	-9- BS/L-T/ E. syl	-10- BS/H-L L-T/SPH	-11- B-WS-BS /CAL	-12- BS-WS/ GW/HYL	-13- BS-WS/ L-T/GEO /HYL-PL	-14- BS-WS/ LICH
LICHEN AND MUSHROOM SPECIES -	(% frequency (F) and % cover (C))													
Mushroom species	F/C	32/.3	12/.1	5/.05	12/.1	2/.1	58/1	2/.03	58/1	18/.2		12/.1	80/1	25/.3
Reindeer lichens														
Cladonia rangiferina						5/.1	51/2	25/1	38/4	23/2		10/1		82/4
Cladonia arbuscula							75/4		38/2	35/3		15/.4		76/9
(Total Cladonia)						(.1)	(6)	(1)	(6)	(5)		(1.4)		(13)
Non-Reindeer Lichens														
Cladonia amaurocrea							6/.2	18/.5	13/.2	15/.3		15/.3		35/4
Cladonia gracilis														40/1
Cladonia-Cladonia Species	18/.2	8/.1	12/.1	23/.2	7/.1	13/.2	61/2	22/.3	50/1	60/4	5/.05	32/3	20/.2	55/1
(Total Cladonia)	(.2)	(.1)	(.1)	(.2)	(.1)	(.4)	(2.2)	(.8)	(1.2)	(4.3)	(.05)	(3.3)	(.2)	(5)
Other Ground Lichens														
Peltigera arbutosa	8/.1			15/.2		13/.4	74/3	10/.1	32/1	7/.3		33/2		72/5
Peltigera canina	2/.02			10/.2	7/.4		6/1	62/4	28/2	18/.4		12/.2	30/1	65/6
Peltigera Species	2/.05		12/1					12/.5	2/.03	15/1		2/.03	5/.05	2/.2
(Total Peltigera)	(.17)		(1)	(.4)	(.4)	(.4)	(4)	(4.6)	(3.03)	(1.7)		(2.23)	(1.05)	(11.2)
Monhrona arcticum							21/3	10/1		33/3		40/2		5/.2
Cetraria islandica							70/2		12/.1	35/1		2/.08		75/2
Cetraria cucullata				3/.03						28/3				82/4
Cetraria richardsonii				(.03)			(2)		(.1)	(1.3)		(.08)		36/1
(Total Cetraria)		2/.02			2/.1	3/.3		15/.2		2/.02				(7)
Stereocaulon Species					7/.2					12/.3		35/2		15/1
Foliose species	2/.02									5/.2			15/.2	
Fruticose species														
ARBOREAL LICHENS GROWING ON FALLEN TWIG LITTER -														
Cetraria pinastri				20/.2	20/.2	93/1	90/1		75/1	32/1	5/.05	18/.2	42/.4	90/1
Parmelia species	2/.02	20/.2	50/1	48/1	53/1	93/2	80/1	52/1	82/1	47/.5	80/1	62/.5	70/1	50/1
Alectoria species	2/.02		15/1	17/.2	5/.05	7/.05	48/2	40/1	35/.4	25/.2		20/.4	28/.3	
Usnea species	2/.02	8/.1	36/1	33/.4	20/.2	18/.2	39/.4	10/.05	17/.2	15/.2	1/.2	28/.3	59/1	
(Total arboreal lichens)	(.06)	(.3)	(3)	(1.8)	(1.45)	(3.25)	(2.6)	(2.05)	(2.6)	(1.9)	(1.25)	(1.4)	(2.7)	(2)
Total Lichen Cover	.75	.52	4.1	2.48	2.35	4.55	20.8	8.68	14.93	17.92	1.3	12.51	5.15	40.7

Table 3 continued

Community Type	White Spruce				Black Spruce						Mixed Spruce			
	-1- A/VIB/ T-F	-2- B/VIB	-3- WS/VIB/ E. arv	-4- WS/T-F/ EQU	-5- A-BS/ COR	-6- BS-A-B/ CAL	-7- BS/LIC	-8- BS/R/ PEL	-9- BS/L-T/ E. syl	-10- BS/H-L L-T/SPH	-11- B-WS-BS /CAL	-12- BS-WS/ GW/HYL	-13- BS-WS/ L-T/GEO /HYL-PL	-14- BS-WS/ LIC
DEAD FALL - Leaf and Twig Litter Peatwood	100/91 90/3	95/91 65/5	88/26 58/15	88/23 92/13	100/83 57/4	100/25 100/10	100/11 80/2	100/28 68/4	100/12 83/3	100/13 48/3	100/94 100/5	98/15 75/5	100/22 95/5	100/26 100/15
EXPOSED SOIL -	10/5					5/.2		8/1	2/.2	3/.1		2/.1		10/.1

FOOTNOTES:

1/ Community type names are abbreviated. Refer to the following page for their full names.

2/ ND = No Data

Key to Abbreviated Community Type Names

WS = White Spruce

- 1) A/VIB/T-F = Aspen/Viburnum/Twin-flower
- 2) B/VIB = Birch/Viburnum
- 3) WS/VIB/E. arv = White Spruce/Viburnum/Equisetum arvense
- 4) WS/T-F/E. syl = White Spruce/Twin-flower/Equisetum sylvaticum

BS = Black Spruce

- 5) A-BS/COR = Aspen-Black Spruce/Cornus
- 6) BS-A-B/CAL = Black Spruce-Aspen-Birch/Calamagrostis
- 7) BS/LIC = Black Spruce/Lichen
- 8) BS/R/PEL = Black Spruce/Rose/Peltigera
- 9) BS/L-T/E. syl = Black Spruce/Labrador-tea/Equisetum sylvaticum
- 10) BS/N-L L-T/SPH = Black Spruce/Narrow-leaf Labrador-tea/Sphagnum

MS = Mixed Spruce

- 11) B-WS-BS/CAL = Birch-White Spruce-Black Spruce/Calamagrostis
- 12) BS-WS/GW/HYL = Black Spruce-White Spruce/Grayleaf Willow/Hylocomium
- 13) BS-WS/L-T/GEO/HYL-PEL = Black Spruce-White Spruce/Labrador-tea/Geocaulon/Hylocomium-Pleurozium
- 14) BS-WS/LIC = Black Spruce/White Spruce/Lichen

trees will replace them and the stand will change character. This replacement starts when the aspen are 60-70 years old. Tree seedlings and suckerlings may be present. When present they are dense. Average densities per hectare of both totaled 114,000 for Betula papyrifera Marsh. subsp. humilis (Regal) Fern. and Raup (Alaska paper birch or birch) and 2,500 for aspen. Birch seedlings out-numbered birch suckerlings 70:1 while aspen suckerlings outnumbered aspen seedlings 12:1. Usually these young trees are short-lived.

Viburnum edule (Michx.) Raf. (Viburnum or highbush cranberry) with over 36,000 stems per hectare, is the most dense tall shrub. It is also quite common, occurring in 80% of the study plots. This shrub is not unique to the aspen sites but seems to do best on them. Rosa acicularis Lindl. (rose), which seems ubiquitous, also does well. It occurred in 88% of the study plots and has a density of 18,500 stems per ha. Salix bebbiana Sarga. (Bebb willow) averages 18% frequency and a density of 1,000 stems/ha. Alnus crispa (Ait.) Pursh (green alder) it has a frequency of 5% and a density of 1,500 stems/ha.

The low shrub, Linnaea borealis L. (twin-flower), is extensive and common. It averages 13% in cover value and occurs in 82% of the plots. Vaccinium vitis-idaea L. (mountain-cranberry) occurs with a frequency of 38% but has an average cover value of only 3%.

Equisetum arvense L. (meadow horsetail) dominates the herb layer. It occurs in 92% of the plots and averages 14% in cover value. Other important herbs are Cornus canadensis L. (bunchberry), Epilobium angustifolium L. (fireweed), Calamagrostis spp [mostly Calamagrostis canadensis (Michx.) Beauv. (or bluejoint)]. They are listed in decreasing order of

both frequency and cover values. All are found in at least 55% of the plots and cover 1-8% of the area. Numerous other herbs occur incidentally and with less than 1% cover values.

Pleurozium schreberi (Brid.) Mitt. (feathermoss) is the only moss attaining a cover value of at least one and it has a frequency of 52%. Several species of lichens occur, but are neither common nor extensive. Leaf and small twig litter covers 91% of the area and is ubiquitous. Dead wood is common but has little cover value. Exposed soil occurs with a cover of 5% and a frequency of 10%.

2) Birch/Viburnum: This community type which is pictured in Figure 5, occurs on cooler sites than the aspen type just discussed. Frost leaves the ground more slowly. It is extensive, and best developed in 110-130-year-old stands, especially in the Tanana Uplands. It occurs mostly in mid-slope positions on slopes with a south or a south-east exposure and a gradient of 7-13%. The average thickness of the organic layer is 13 cm (5 in).

The flora in the birch/Viburnum type is poor, averaging 27.0 species per stand. The average density of all the tree species totals 735 trees, 13 sapling trees, and 0 seedling trees per hectare; while the average densities for willow and non-willow tall shrubs total 0 and 40,374 stems/ha respectively. The average cover in percent totals 3.5 for all low shrubs, 33.2 for herbs, 6.1 for moss and .5 for lichens.

Paper birch is the dominant tree, occurring with a frequency of 100% and an average density of 622 trees/ha (Table 3). These trees average 20.3 cm (8.0 in) dbh in 110-year-old stands and 30.8 cm (12.1 in) in 140-year-old stands. Picea glauca (Moench) Voss (white spruce) occurs with

a frequency of 52% and a density of 113 trees/ha. The white spruce average 14.8 cm (5.8 in) dbh in the younger stands and 39.9 in the older ones. Both birch and white spruce saplings occur with a frequency of 30% and a density of 6-7 trees/ha. Tree seedlings are not found.

Of the tall shrubs, rose occurs with the greatest frequency, and highbush cranberry with the greatest density. Frequency values are 95% for rose and 75% for highbush cranberry. Density values are 20,500 for highbush cranberry and 18,200 for rose. Green alder has a frequency value of 22% and a density of 1,500 stems/ha. No willows were recorded.

The low shrubs, twin-flower and Ribes triste Pall. (American red currant) occur but are neither common or extensive.

In the herb layer, bunchberry, with a frequency value of 72% is the most common and Equisetum pratense Ehrh. (meadow horsetail), and Galium aparine spp (mostly bluejoint) are common, occurring with a frequency of at least 40% and a cover of 8% and 27% respectively.

Pleurozium schreberi is the dominant moss. It occurs with a frequency of 30% and a cover of 2%. Lichens are present but not common and not extensive.

Litter covers 91% of the surface. Dead wood has a frequency value of 65% and a cover value of 5%. No exposed soil was recorded.

3) White Spruce/Viburnum/Equisetum arvense: This community type, which is pictured in Figure 6, is the most stable or oldest successional stage occurring on upland white spruce sites. It is well-developed as 150-year-old stands. Both the Aspen/Viburnum/Twin-flower type and Birch/Viburnum type will in time develop into this type. The soils in this white spruce type are cooler than in the hardwood types. That is, the

a frequency of 52% and a density of 113 trees/ha. The white spruce average is 14.6 m (48 in) dbh in the younger stands and 17.9 in the older ones. Both birch and white spruce saplings occur with a frequency of 30% and a density of 6-7 trees/ha. Tree seedlings are not found. Of the tall shrubs, rose occurs with the greatest frequency, and highbush cranberry with the greatest density. Frequency values are 82% for rose and 52% for highbush cranberry. Density values are 20,000 for highbush cranberry and 18,500 for rose. Green alder has a frequency value of 52% and a density of 1,500 stems/ha. No willows were recorded. The low shrubs, twin-flower and Ribes (R. luteum, R. americanum) occur but are neither common or extensive. In the herb layer, bunchberry, with a frequency value of 52% is the most common and *Eriogonum griseum* Ehrh. (meadow horsetail), and *Salmonberry* (a red-flowered blueberry) are common, occurring with a frequency of at least 40% and a cover of 8% and 52% respectively. *Polygonum sachalinense* is the dominant moss. It occurs with a frequency of 30% and a cover of 52%. Lichens are present but not common and not extensive. Lichen covers 91% of the surface. Dead wood has a frequency value of 62% and a cover value of 52%. No exposed soil was recorded.

3) *White Spruce/Viburnum/Aspen* (this community type, which is pictured in Figure 5, is the most stable or oldest successional stage occurring on upland white spruce sites. It is well-developed as 150-year-old stands. Both the *Aspen/Viburnum/Twin-flower* type and *Sticky Viburnum* type will in time develop into this type. The soils in this white spruce type are cooler than in the hardwood types. That is, the

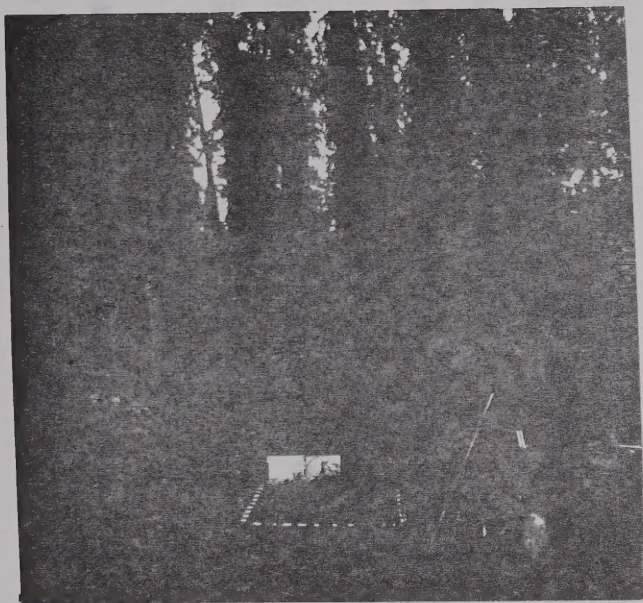


Figure 6.--White spruce/Viburnum/Equisetum arvense community type occurring on climax white spruce sites in interior Alaska. The spruce trees in this stand (96) are about 150 years in age.

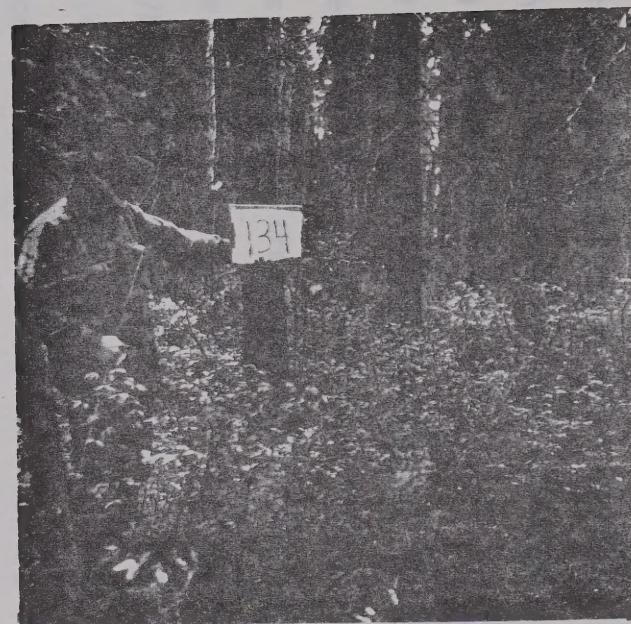


Figure 7.--White spruce/twin flower/Equisetum community type occurring on climax white spruce sites in interior Alaska. The spruce trees in this stand (134) are about 110 years in age.

frost is slower in its spring retreat than it is in the hardwood types (Table 2). This type is common on slopes which have a southerly exposure, a 10-25% gradient, and a mid-slope to upper slope position. The thickness of the organic layer averages 12 cm.

The flora in white spruce/Viburnum/Equisetum arvense stands is rich, averaging 37 species per stand. The average density for all tree species totals 548 trees, 29 sapling trees, and 3,500 seedling trees per hectare; while the willow density is zero, and the non-willow species density totals of 20,062 stems/ha. The average percent cover values are 2 for low shrub, 12 for herb, 67.4 for moss and 4 for lichen species.

White spruce dominates the stand with an average density of 744 trees/ha (Table 3). Trees in 150-year-old stands average 26.0 cm (10.2 in) dbh. A few large old birch and aspen may occur. In the same age stands the birch will average 20.4 cm (8.0 in) and the aspen 34.0 cm (13.4 in) dbh. White spruce also dominates the sapling and seedling strata but aspen, birch and Populus balsamifera L. (balsam poplar) do occur and, especially the seedlings, can be quite numerous.

The tall shrubs are rose, highbush cranberry, and green alder. Rose is dominant with a frequency of 70% and a density of 12,300 stems/ha. Highbush cranberry follows with a frequency of 40% and a density of 7,500 stems/ha, while green alder has a frequency of 5% and a density of 188 stems/ha. These figures are all lower than for the younger aspen and birch types already discussed. No willows were found.

Twin-flower and Shepherdia canadensis (L.) Nutt. (buffaloberry) are the low shrubs that may occur. The former has a frequency value of 15%, the latter 8%. Both have a cover value of 1%.

Forest is slower in its spring recovery than it is in the hardwood types (Table 2). This type is common on slopes which have a southerly exposure, a 10-25% gradient, and a mid-slope to upper slope position. The thickness of the organic layer averages 12 cm.

The flora in white spruce/*Picea canadensis* stands is rich, averaging 37 species per stand. The average density for all tree species totals 548 stems, 29 sapling trees, and 3,800 seedling trees per hectare. While the white spruce density is zero, and the non-white spruce density totals 20,000 stems/ha. The average percent cover values are 2 for low shrub, 12 for herb, 67.4 for moss and 4 for lichen species.

White spruce dominates the stand with an average density of 548 stems/ha.

(Table 3). Trees in 120-year-old stands average 26.0 cm (10.2 in) dbh.

A few large old birch and aspen may occur. In the same age stands the birch will average 30.4 cm (12.0 in) and the aspen 34.0 cm (13.4 in) dbh. White spruce also dominates the sapling and seedling strata but aspen, birch and *Populus balsamifera* L. (balsam poplar) do occur and, especially the seedlings, can be quite numerous.

The tall shrubs are rose, highbush cranberry, and green alder. Rose

is dominant with a frequency of 70% and a density of 12,300 stems/ha.

Highbush cranberry follows with a frequency of 40% and a density of 7,500

stems/ha. While green alder has a frequency of 25 and a density of 100

stems/ha. These figures are all lower than for the younger aspen and

birch types already discussed. No willows were found.

Twin-flower and *Shepherdia canadensis* (L.) Nutt. (buffalobery) are

the low shrubs that may occur. The former has a frequency value of 12,

the latter 52. Both have a cover value of 12.

Equisetum arvense and Geocaulon lividum (Richards.) Fern. are the most extensive herb species. Each has a cover value of 4%. However, the former occurs with 82% frequency while the latter with 55% frequency. Galium boreale L. (northern bedstraw) is common but not extensive. Its frequency and cover values are 40% and .4% respectively. Other species occur but with both low frequency and cover values.

Hylocomium splendens (Hedw.) B.S.G. (feathermoss) is the most common and extensive moss. Its frequency and cover values are 88% and 62% respectively. Pleurozium schreberi occurs with frequency and cover values of 25% and 5% respectively. Other less common species do occur. Parmelia spp. and Usnea spp. are two arboreal lichens that are frequently present on the tree branches and twig litter. They occur on the forest floor twig litter with frequencies of 50 and 36 percent and cover values of 1%.

Litter occurs with a frequency of 88% and a cover of 26%. The moss layers quickly incorporate and conceal the litter. Dead wood occurs with a frequency of 58% and a cover of 15%.

4) White Spruce/Twin-flower/Equisetum sylvaticum: This community type which is pictured in Fig. 7, is the river bottom counterpart to the oldest upland white spruce type. It can be well developed in 110-year-old stands, however it maintains its distinctness even in 270-year-old stands. This river bottom type has the coolest soil temperatures of any White spruce site type, i.e. the seasonal frost is slow to retreat (Table 2). It is found on islands and river margins in the Tanana-Yukon and Kuskokwim River drainages. Along these rivers there is little slope gradient. The organic layer averages 8 cm (3 in) in depth above layers of silt. The silt is underlain by river gravels and sands. Except in time of flood,

Sparganium angustifolium (Michx.) Torr. are the

most extensive herb species. Each has a cover value of 45. However, the former occurs with 85% frequency while the latter with 55% frequency. Galium boreale L. (northern bedstraw) is common but not extensive. Its frequency and cover values are 40% and 45 respectively. Other species occur but with low frequency and cover values.

Phytolacca sp. (Hb.) 5.2.5. (Verbenaceae) is the most common

and extensive moss. Its frequency and cover values are 55% and 55% respectively. Platanus acerifolia occurs with frequency and cover values of 55% and 55% respectively. Other less common species do occur. Samolus spp. and Utricularia spp. are two other species that are frequently present on the tree branches and twig litter. They occur on the forest floor with litter with frequencies of 50 and 55 percent and cover values of 15.

Litter occurs with a frequency of 55% and a cover of 55%. The moss layers quickly incorporate and conceal the litter. Dead wood occurs with a frequency of 55% and a cover of 15%.

4) White Birch (Betula papyrifera) This community type which is pictured in Fig. 7, is the river bottom counterpart to the old-growth white spruce type. It can be well developed in 10-year-old stands, however it maintains its distinctness even in 250-year-old stands. This river bottom type has the coolest soil temperatures of any white spruce site type. In the seasonal frost is slow to retreat (Table 2). It is found on islands and river margins in the Tahquamenon and Keweenaw River drainages. Along these rivers there is little slope gradient. The organic layer averages 8 cm (3 in) in depth above layers of silt. The silt is underlain by river gravels and sands. Except in time of flood,

these sites are well-drained and permafrost does not exist.

The flora in this riverbottom type averages 28 species per stand, which is fewer than occurs in the upland counterpart to the stand. The average density for all tree species totals 700 trees, 10 saplings, and 1,210 seedlings per hectare. No willows were recorded, and the average density for non-willow tall shrubs totaled 1,900. The average percent cover values totalled 15.1 for low shrubs, 16.4 for herbs, 77.5 for mosses and 2.5 for lichens.

White spruce trees dominate with a density of 580 trees/ha (Table 3). In 100-year-old stands they will average 23.9 cm (9.4 in) dbh while in 270-year-old stands they average 31.9 cm (12.6 in) dbh. Some small diameter (11.0 cm or 4.0 in) and a few large diameter (27.0 cm or 10.6 in) balsam poplar can be found. Saplings are few. White spruce seedlings can be numerous. They have a frequency of 22% and a density of 1,200 seeds/ha. Few grow more than 10 cm tall.

Rose is the dominant tall shrub. It has a frequency value of 87 and a density of 19,300 stems/ha. Highbush cranberry, green alder and Alnus tenuifolia Nutt. (thinleaf alder) may also occur.

The most dominant low shrub is twin-flower. It's cover and frequency values are 8% and 85%. Mountain-cranberry, with 6% cover and 85% frequency, is also extensive. Spirea beauverdiana Schneid. (beauverd spirea) occurs with 13% frequency and 1% cover. This species occurs in small amounts in several of the community types, however, it is best represented in this riverbottom white spruce type. No willows were observed.

Equisetum species dominate the herb layer. Equisetum sylvaticum L. (woodland horsetail) is the most extensive while Equisetum arvense is most frequent. Their cover values are 7% and 5% while their frequency

these sites are well-drained and groundwater does not exist.

The flora in this riverbottom type consists of species per stand, which is fewer than occurs in the inland community on the same. The average density for all three species totals 700 trees, 10 seedlings, and 1,210 seedlings per hectare. No willows were recorded, and the average density for non-willow tall shrubs totaled 1,900. The average herbaceous cover values totaled 15.1 for low shrubs, 28.4 for herbs, 77.8 for mosses and 2.2 for lichens.

White spruce trees dominate with a density of 350 stems/ha (Table 3). In 100-year-old stands they were average 23.9 cm (9.4 in) dbh while in 250-year-old stands they average 37.2 cm (14.6 in) dbh. Some trees in diameter (11.0 cm or 4.3 in) and a few large diameter (27.0 cm or 10.6 in) balsam poplar can be found. Seedlings were few. White spruce seedlings can be numerous. They have a frequency of 225 and a density of 1,100 stems/ha. Few grow more than 20 cm tall.

Bass is the dominant tall shrub. It has a frequency value of 10 and a density of 19,210 stems/ha. Highbush cranberry, green alder and *Alnus tenuifolia* will. (tenuifolia alder) may also occur.

The most dominant low shrub is twin-flower. It's cover and frequency values are 87 and 85%. Mountain-cranberry, with 32 cover and 100 frequency, is also extensive. *Salix lasiolepis* (lasiolepis) occurs with 132 frequency and 12 cover. This species occurs in small amounts in several of the community types, however, it is best represented in this riverbottom white spruce type. No willows were observed.

Forsetia species dominates the herb layer. *Forsetia viridis* (woodland horsetail) is the most extensive with *Forsetia viridis* is most frequent. Their cover values are 74 and 52 while their frequency

values are 33% and 58% respectively. Bunchberry and Geocaulon lividum are also common. Numerous other herbaceous species occur.

Hylocomium splendens is the dominant moss. It occurs with a frequency of 92% and a cover of 60%. Pleurozium schreberi and Ptilium crista-castrensis (Hedw.) DeNot. (feathermoss) are common. Several other species may also occur. The arboreal lichens Parmelia spp. and Usnea spp., growing on twig litter on the ground have frequency values of 48% and 33% while their cover is around 1%.

Litter and dead wood both have frequency values around 90% and cover values of 23 and 13% respectively. The moss layer rapidly engulfs these dead materials.

2. Black Spruce Sites. -- The following 6 mature community types (numbered 5-10) were identified as occurring within the black spruce climax type: 5) Aspen-Black Spruce/Cornus, 6) Black Spruce-Aspen-Birch/Calamagrostis, 7) Black Spruce/Lichen, 8) Black Spruce/Rose/Peltigera spp., 9) Black Spruce/ Labrador-tea/Equisetum sylvaticum, and 10) Black Spruce/Narrow-leaf Labrador-tea/Sphagnum spp. Since fire is a continuing part of the environment on black spruce sites few of these types ever attain climax status. However, it is possible for types 7-10 to do so. Types 5 and 6, the Aspen-Black Spruce/Cornus and the Black Spruce-Aspen-Birch/Calamagrostis types, must have fire in order to perpetuate themselves. Types 5-7 occur on the drier, warmer locations while types 8-10 prefer colder locations. Type 8 is relatively dry, type 9 occurs in more moist areas, while type 10 is quite moist though open water seldom exists.

5) Aspen-Black Spruce/Cornus: This community type, which is pictured in Fig. 8, occurs on the warmest upland black spruce sites but on sites

values are 133 and 582 respectively. Bombus and Halictus are also common. However, other bumblebee species occur.

Hylocichla ustulata is the dominant bird. It occurs with a frequency

of 52 and a cover of 60. Phoebastria immutabilis and Fulica americana

also occur. The arboreal Ichneumonidae are common. Several other species may

also occur. The arboreal Ichneumonidae are common. Several other species may

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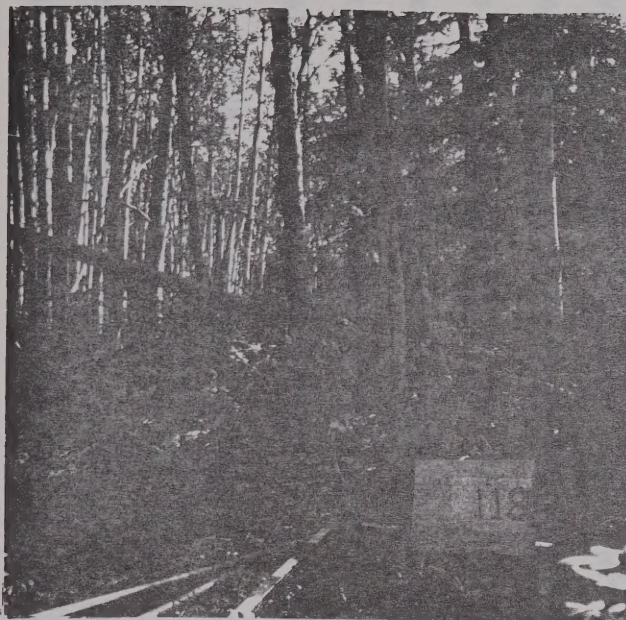


Figure 8.--Aspen-Black spruce/Cornus community type occurring on climax black spruce sites in interior Alaska. The trees in this stand (118) are about 80 years in age.

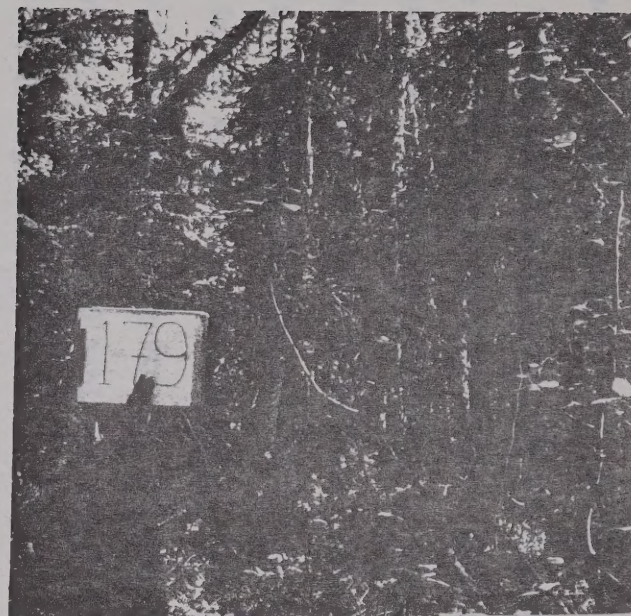


Figure 9.--Black spruce-Aspen-Birch/Calamagrostis community type occurring on climax black spruce sites in interior Alaska. The trees in this stand (179) are about 60 years in age.

which are cooler than the aspen-white spruce sites. Frost starts to leave the ground in early June. By August it may be found 63 cm (28.3 in) below the surface or it may be too deep to measure (deeper than 90 cm or 35.4 in). This type is common on slopes that have a southernly exposure, a gradient of 0-15% and a mid-slope position or in slightly raised areas on the upland valley floor. The organic layer is shallow, averaging 8 cm (3 in). This type is well-developed in 65-80-year-old stands.

The flora in the Aspen-Black Spruce/Cornus type is moderately rich with an average of 40.3 species per stand. The average density for all tree species totals 2,086 trees, 40 saplings and 10,375 seedlings per hectare; while the average density for all willows totals 333/ha, and the average density for all non-willow tall shrubs averages 131,111/ha. The average percent cover values, totaled 17 for all low shrubs, 10.1 for all herbs, 10.8 for all moss, and 2.4 for all lichen species.

In seventy-year-old stands the aspen trees, with an average dbh of 12.9 cm (5.1 in), and a density per hectare of 1,500 (Table 2), dominate. In these same stands Picea mariana (Mill.) B.S. & P. (black spruce) trees, with an average diameter of 5.8 cm (2.3 in) and a density of 451 trees per hectare, occur with a frequency of 60%. Some birch may occur as well as an occasional white spruce relic. Black spruce saplings and seedlings with densities of 36/ha and 6,600/ha, are both more common and extensive than those of other tree species.

Rose is the dominant tall shrub. It has a density of 3,000 stems/ha and a frequency value of 35%. Green alder has a comparable density, 3,300 stems/ha but occurs less frequently -- its frequency value is 10%. Occasionally highbush cranberry may be found. Bebb willow, though not common,

which are cooler than the open-white spruce sites. Frost starts to fall
the ground in early June. By August it has to about 45 cm (18 in) below
the surface on 15 May the top layer is frozen (about 20 cm or 8 in).
(a). This type is common on slopes that have a southerly exposure, a
gradient of 0-15% and a side-slope section on the slightly raised areas
on the island valley floor. The organic layer is shallow, averaging 5
cm (2 in). This type is well-developed in 45-55-year-old stands.

The third in the *Aspen-Betula* community type is moderately rich
with an average of 50% species per stand. The average density for all
tree species is 1,000 trees, 40 saplings and 10,000 seedlings per
hectare; while the average density for all shrubs is 30,000, and
the average density for all non-woody tall shrubs is 10,000.
The average percent cover values, based on all low shrubs, 10%
for all herbs, 10% for all mosses, and 5% for all lichen species.

In twenty-year-old stands the open forest, with an average of 15
15% on (a) in, and a density per hectare of 1,500 (about 2) seedlings.
In these same stands *Picea mariana* (Mill.) B.S. 5% (about 100) trees,
with an average diameter of 5.8 cm (2.3 in) and a density of 421 trees
per hectare, occur with a frequency of 60%. Some birch may occur as well
as an occasional white spruce. Black spruce saplings are scattered
with densities of 30/ha and 5,000/ha, and both were common and extensive
than those of other tree species.

Now is the dominant call shrub. It has a density of 5,000 stems/ha
and a frequency value of 35%. Green alder has a comparable density, 3,000
stems/ha but occurs less frequently -- its frequency value is 10%. Dominant
any aldered community may be found. Herb willow, though not common,

is the only willow to occur. It has a frequency of 7% and a density of 300 stems/ha.

Mountain-cranberry and Vaccinium uliginosum L. (bog blueberry) are important tall shrubs. Their respective frequency values are 73% and 52%, while their cover values are 11% and 3%. Twin-flower, Ledum groenlandicum Oeder (labrador-tea), and American red currant also occur, but with low cover and frequency values.

The dominant herb species is bunchberry. It has a frequency of 98% and a cover of 6%. Calamagrostis spp. (mostly bluejoint) occurs frequently but in small amounts. Its frequency value is 60% and cover value is 1%. Numerous other species are occasionally present, but in small amounts.

The feathermosses, Hylocomium splendens and Pleurozium schreberi, dominate the moss layer. Each has a frequency value of 45% and cover values are 5 and 4%, respectively. Drepanocladus uncinatus (Hedw.) Warnst. is also common. Its frequency value is 40% and cover is 1%. Several lichens occur but only Parmelia spp. appears common with a frequency value of 53% and cover of 1%.

The litter accumulation layer is well exposed. It has a frequency of 100% and a cover of 88% and includes some dead wood.

6) Black Spruce-Aspen-Birch/Calamagrostis: This upland black spruce type, which is pictured in Fig. 9, occurs on sites which are somewhat cooler than those where the aspen-black spruce type occurs. Late in June the seasonal frost has receded 48 cm (18.9 in) below the surface. In August this active layer will have a minimum depth of 56 cm (22 in) and a maximum depth of more than 100 cm (39.4 in) depending on the site. This type occurs on slopes of any exposure, 3-21% slope, and on mid-slope

is the only willow to occur. It has a frequency of 15 and a density of 100 stems/m².

Mountain-cranberry and Vaccinium uliginosum L. (bog blueberry) are frequent tall shrubs. Their respective frequency values are 15 and 50, while their cover values are 15 and 35. Twin-flower, Ledum palustre L., and Andromeda (Andromeda) and current also occur, but with low cover and frequency values.

The dominant herb species is bunchberry. It has a frequency of 100 and a cover of 65. Calluna vulgaris L. (heath blueberry) occurs frequently but its small stature. Its frequency value is 100 and cover value is 15. Numerous other species are occasionally present, but in small amounts. The feathermosses, Hypnum revolutum L. and Hypnum revolutum L. dominate the moss layer. Each has a frequency value of 45 and cover values are 5 and 45, respectively. Pregeacanthus wrightii (Hook.) Muhl. is also common. Its frequency value is 45 and cover is 15. Several lichens occur but only Parasola spp. appears common with a frequency value of 55 and cover of 15.

The litter accumulation layer is well exposed. It has a frequency of 100 and a cover of 65 and includes some dead wood.

8) Black Spruce-Aspen-Birch/Calluna vulgaris: This is a black spruce type, which is pictured in Fig. 9, occurs on sites which are somewhat cooler than those where the aspen-black spruce type occurs. Late in June the seasonal frost has reached 48 cm (18.9 in) below the surface. In August this active layer will have a minimum depth of 55 cm (22 in) and a maximum depth of more than 100 cm (39.4 in) depending on the site. This type occurs on slopes of any exposure, 3-25% slope, and on micro-

and on mid-slope or upper slope positions. The organic layer is moderately thick, 16 cm (6.3 in). This mixed spruce-hardwood type is well-developed in 70-100-year-old stands.

The flora in the Black Spruce-Aspen-Birch/Calamagrostis type is somewhat poor, averaging 32.3 species/stand. The average density of all the tree species totals 2,108 trees, 828 saplings, and 10,292 seedlings per hectare; while the average density of the willow species totals 31/ha, and the non-willow tall shrubs totals 4,000/ha. The average percent cover values total 13.4 for low shrubs, 10.1 for herbs, 64.5 for moss and 4.6 for lichen species.

Black spruce dominates this community type. These trees have a frequency value of 92%, and a density of 1,700/ha. Black spruce have a frequency of 98% and a density of 800/ha, while seedlings have a frequency of 72% and a density of 10,100/ha. Both birch (114 trees/ha, 10 saplings/ha, and 42 seedlings/ha) and aspen (254 trees/ha, 12 saplings/ha, and 83 seedlings/ha) occur but have much lower densities than black spruce. In 100-year-old stands the black spruce trees will average 12.0 cm (4.7 in) dbh, while the birch will range from 16.0-24.5 cm (6.3-9.6 in) dbh and the aspen will average 13.0 cm (5.1 in) dbh.

Green alder and rose dominate the tall shrub layer. They occur with respective frequency values of 28 and 18% and densities of 2,000 stems/ha each. Salix scouleriana Barratt (Scouler willow) is the only willow to occur and it is not common.

Mountain-cranberry and bog blueberry are important low shrubs. They occur with 95% and 47% frequencies and 9% and 3% cover values, respectively.

and an mid-1000 or upper 4000 position. The organic layer is moderately
rich, 10 cm (6.3 in). This mixed surface-barren type is well-developed
in 70-100-year-old stands.

The flora in the Black Spruce-Juncus-Carex wetlands type is somewhat
poor, averaging 35.3 species/m². The average density of all the
true species totals 5,108 stems, 850 seedlings, and 10,500 seedlings per
hectare; while the average density of the winter species totals 31/m².
and the non-winter (all) species totals 4,000/m². The average percent cover
values total 71% for low shrubs, 10.1 for herbs, 64.5 for moss and 4.6
for lichen species.

Black spruce dominates this community type. There are some 5 to 6-
decade values of 95%, and a density of 1,500/m². Black spruce has a fre-
quency of 95% and a density of 850/m², while seedlings have a frequency
of 75% and a density of 10,700/m². Black birch (1/4 trees/m², 10 seedlings/m²)
and 15 seedlings/m² and aspen (5% trees/m², 12 seedlings/m²) and
8% seedlings/m² occur but have some densities than black spruce.
In 100-year-old stands the black spruce stems will average 12.0 cm (4.7
in) dbh, while the black will range from 10.0-24.2 cm (4.0-9.5 in) dbh
and the aspen will average 13.0 cm (5.1 in) dbh.

Green alder and willow dominate the tall shrub type. They occur with
relative frequency values of 95 and 100 and densities of 5,000 stems/m²
each. *Salix glauca* var. *glauca* (2000 stems/m²) is the only willow to
occur and is not common.

Mountain-spruce and bog blueberry are important low shrubs. They
occur with 95% and 95% frequency and 95 and 32 cover values, respectively.

Calamagrostis spp. (mostly bluejoint) and Geocaulon lividum are the most important herbaceous species. The former dominates with a cover of 6% and a frequency of 85 percent. The latter has a cover of 2% and a frequency of 50%.

In the moss layer both Pleurozium schreberi and Hylocomium splendens are present but the former is the more dominant. Its cover value is 47%, while its frequency is 95%. On the other hand, Hylocomium splendens has a cover of 14% and a frequency of 65%. Polytrichum spp. and Dicranum spp. occur in small quantities, with frequencies of 38 and 35 percent. The arboreal lichens, Parmelia spp. Cetraria pinantri (Scop.) S. Gray, which are found on the ground on the twig litter, occur in 93% of the plots but with only 2% and 1% cover values.

Litter and dead wood occur frequently (100% frequency) and with 25% and 10% cover values. Occasionally bare soil occurs.

7) Black Spruce/Lichen: This community type, which is pictured in Fig. 10, comes next in the sequence of decreasing site temperatures. It may be located in any position on the slope, and on slopes of any exposure and most gradients (0-15%). Its organic soil is moderately deep (16 cm or 6.3 in). This type is well-developed in 60-year-old stands. The flora in this Black Spruce/Lichen type is moderately rich, averaging 37 species per stand. The average density of all the tree species totals 2,693 trees, 2,273 saplings, and 15,624 seedlings per hectare; while the average density of all the willow species total 844/ha and of all the non-willow tall shrub species total 469/ha. The average percent cover values total 24.6 for low shrub, 3.6 for herb, 72.8 for moss, and 20.8 for lichen species.

Cytisus spp. (mostly binaria) and Senecio spp. are the most important herbaceous species. The former dominates with a cover of 65 and a frequency of 85 percent. The latter has a cover of 15 and a frequency of 50.

In the moss layer both Cladonia spp. and Hylocomium spp. are present but the former is the more dominant. Its cover value is 55, while its frequency is 85. On the other hand, Hylocomium spp. has a cover of 15 and a frequency of 50. Polytrichum spp. and Grimmia spp. occur in small quantities, with frequencies of 50 and 35 percent. The highest lichens, Parmelia spp. Cetraria binaria (20%), 2. 5%, which are found on the ground on the left litter, occur in 55 of the plots but with only 25 and 15 cover values.

Litter and dead wood occur frequently (100% frequency) and with 55 and 100 cover values. Occasionally bare soil occurs.

7) Black Spruce/Lichen: This community type, which is pictured in

Fig. 10, comes next in the sequence of decreasing site temperatures.

It may be located in any position on the slope, and on slopes of any exposure and most gradients (0-100%). Its organic soil is moderately deep (10 cm or 8.1 in.). This type is well-developed in 60-year-old stands. The flora in this Black Spruce/Lichen type is moderately rich, averaging 35 species per stand. The average density of all the tree species totals 2,681 trees, 5,273 saplings, and 15,624 seedlings per hectare while the average density of all the willow species totals 804/m² and of all the non-willow tall shrub species totals 489/m². The average percent cover values total 52.6 for low shrub, 3.8 for herb, 75.8 for moss, and 10.8 for lichen species.

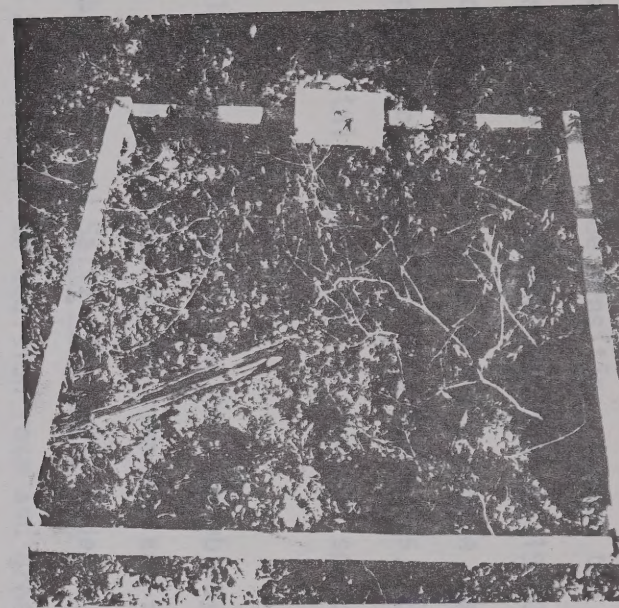


Figure 10.--Black spruce/Lichen community type occurring on climax black spruce sites in interior Alaska. A is a general view in which the trees are about 70 years in age. B is a close-up of a lichen patch.

Figure 10

Figure 10 is a photograph of the interior of the building. The photograph shows the interior of the building, which appears to be a large, open space. The floor is made of concrete, and there are some markings on it. The walls are made of brick, and there are some windows visible in the background. The lighting is somewhat dim, and the overall appearance is that of an old, possibly abandoned, building.



Black spruce trees, saplings, and seedlings are very abundant. Their frequency is almost 100% and the densities of both the trees and saplings is above 2,200/ha, while that of the seedlings is 15,500/ha. Occasionally a tree, sapling or seedling birch or a white spruce tree will occur. In 60-year-old stands the black spruce trees average 5.4 cm (2.1 in) dbh, the birch 6.8 cm (2.7 in) dbh and the relic white spruce 19.9 cm (7.8 in) dbh.

Several willow species occur in the tall shrub layer. Scouler willow, with density and frequency values of 590 stems/ha and 5%, is the most important but Bebb willow and Salix alaxensis (Anderss.) Cov. (fettleaf willow) may also be present. In addition rose and green alder are found. Rose is the more common with frequency and density values of 10% and 340 stems/ha.

Mountain-cranberry is extensive. This low shrub has a 7% cover and a 100% frequency. Bog blueberry and Labrador-tea are also important. Blueberry is the most frequent while Labrador-tea is the most extensive. Frequency values are respectively 64% and 43%, and cover values are 5% and 7%.

The herb layer is not well developed. The most extensive is bluejoint and Geocaulon lividum which occur in about 50% of the plots and with cover values of 1%.

Pleurozium schreberi is the dominant moss. It occurs with a frequency of 98% and a cover of 45%. The following species, listed in decreasing order of frequency, are also important. Polytrichum spp. (F = 76%), Dicranum spp. (F = 68%), and Hylocomium splendens (F = 65%). Their respective cover values are 6, 3, and 15 percent. Other moss species also occur in small quantities.

Black spruce trees, saplings, and seedlings are very abundant. Their frequency is almost 100% and the densities of both the trees and saplings is about 2,500/m², while that of the seedlings is 15,000/m². Occasionally a tree, sapling or seedling grows on a white spruce tree which occurs in 60-year-old stands. The black spruce trees average 2.4 m (7.9 ft) dbh, the birch 8.5 m (27.9 ft) dbh and the white spruce 10.0 m (32.8 ft) dbh.

Several Willow species occur in the tall shrub layer. *Salix glauca* willow, with density and frequency values of 250 stems/m² and 57%, is the most important but *Salix alba* and *Salix glauca* (Anders.) Cov. (leafless willow) may also be present. In addition rose and green alder are found. Rose is the most common with frequency and density values of 10% and 360 stems/m².

Mountain-cranberry is extensive. This low shrub has a 7% cover and a 100% frequency. Bog blueberry and Labrador-tea are also important. Blueberry is the most frequent with Labrador-tea is the most extensive. Frequency values are respectively 60% and 42%, and cover values are 3% and 7%.

The herb layer is not well developed. The most extensive is bluejoint and *Andropogon furcatus* which occupy about 10% of the plot and with cover values of 1%.

Platanus occidentalis is the dominant moss. It occurs with a frequency of 92% and a cover of 42%. The following species, listed in decreasing order of frequency, are also important: *Polypodium* sp. (7 = 75%), *Dicranum* sp. (7 = 68%), and *Hypnum splendens* (7 = 65%). Their respective cover values are 6, 1, and 15 percent. Other moss species also occur in small quantities.

The lichen layer is very well developed in this community type. The arboreal species, Parmelia spp. and Cetraria pinastri, which grow on the twig litter on the ground, are the most frequent. However, Peltigera aphthosa (L.) Willd., the reindeer lichens Cladina arbuscula (Wallr.) Hale & W. Culb. and Cladina rangiferina (L.) Harm. and Cetraria islandica (L.) Ach. have the most cover. The cover of the latter four ranges from 1-4%.

Litter and dead wood are also present. Their cover values are 11 and 2%, respectively, while their frequency values are 100 and 80 percent.

8) Black Spruce/Rose/Peltigera spp: This community type, which is pictured in Fig. 11, was found on the gentle (0-3%), lower, east-facing slopes. These sites have moderately thick organic soils (15 cm or 5.9 in) and the frozen ground retreats at about the same rate as in the black spruce/lichen type. The flora in the Black Spruce/ Rose/Peltigera spp. type is moderately rich, averaging 36 species per stand. The average density of all tree species totals 234 trees, 58 saplings, and 14,374 seedlings per hectare; while the average density for all the willow species totals 2,187, and the average density for the non-willow tall shrubs totals 4,438. The average percent cover values total 7.6 for low shrub, 3.4 for herb, 72.9 for moss, and 8.7 for lichen species. This type is well-developed in 60-80-year-old stands.

The trees, saplings, and seedlings in these rather open stands are black spruce with an occasional aspen relic. The black spruce trees have a density of 210 trees/ha, and a frequency of 100%. In 80-year-old stands the trees have an average dbh of 7.1 cm (2.8 in). Saplings occur with a frequency of 75% and a density of 58/ha, while the seedlings have a frequency of 75% and a density of 14,300/ha.

The lichen layer is very well developed in this community type. The arboreal species, *Parmelia* spp. and *Cetraria pinastri*, which grow on the twig litter on the ground, are the most frequent. However, *Peltigera aphogona* (L.) Willd., the reindeer lichen *Cladonia arbuscula* (Wolff) Hale & W. Culb. and *Cladonia rangiferina* (L.) Horn. and *Cetraria islandica* (L.) Ach. have the most cover. The cover of the latter four ranges from 1-4%.

Litter and dead wood are also present. Their cover values are 17 and 12, respectively, while their frequency values are 100 and 80 percent. 8) Black Spruce/Rose-Peltigera spp. This community type, which is pictured in Fig. 11, was found on the gentle (0-3%), lower, east-facing slopes. These sites have moderately thick organic soils (15 cm or 2.5 in) and the frozen ground retreats at about the same rate as in the black spruce/lichen type. The flora in the Black Spruce/Rose-Peltigera spp. type is moderately rich, averaging 36 species per stand. The average density of all tree species totals 234 trees, 58 saplings, and 14,314 seedlings per hectare; while the average density for all the willow species totals 2,187, and the average density for the non-willow tall shrubs totals 4,438. The average percent cover values total 7.6 for shrubs, 2.4 for herb, 72.2 for moss, and 8.3 for lichen species. This type is well-developed in 60-80-year-old stands.

The trees, saplings, and seedlings in these rather open stands are black spruce with an occasional aspen. The black spruce trees have a density of 210 trees/ha, and a frequency of 100%. In 60-year-old stands the trees have an average dbh of 7.1 cm (2.8 in). Saplings occur with a frequency of 75% and a density of 56/ha, while the seedlings have a frequency of 12% and a density of 14,300/ha.

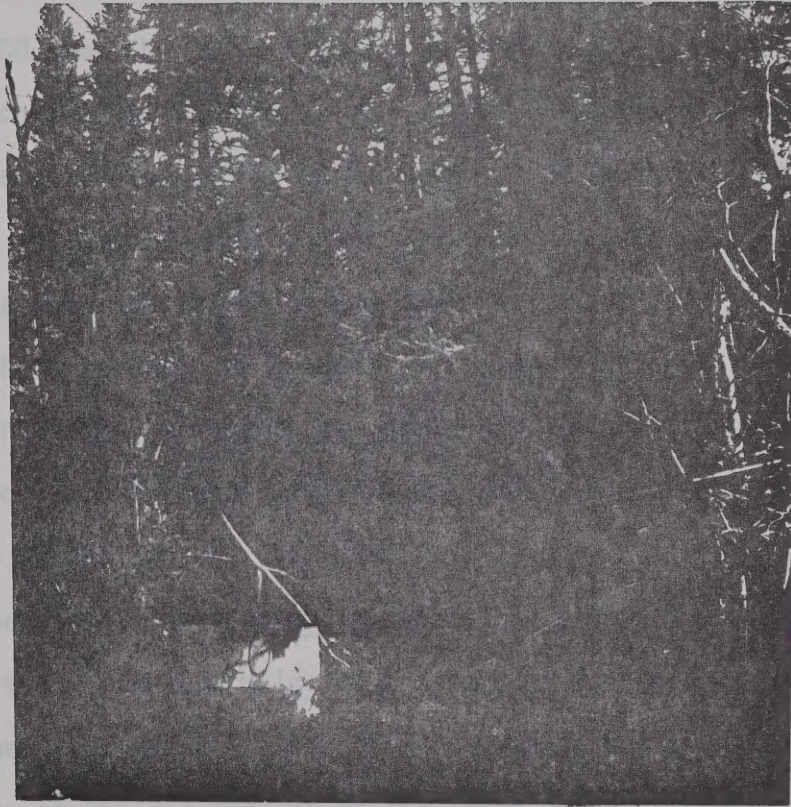


Figure 11.--Black spruce/Rose/Peltigera community type occurring on climax black spruce sites in interior Alaska. The trees in this stand are about 50 years in age.



Figure 11--Black spruce/Populus tremula community
type occurring on former black spruce sites in interior
Alaska. The trees in this stand are about 50 years in
age.

Both Bebb willow and Salix glauca L. (grayleaf willow) may occur. The former is the most abundant willow, with a density of 2,000 stems/ha and a frequency value of 32%. Rose is even more extensive. It has a density of 4,400 stems/ha and a frequency of 92%.

The most common low shrub species is mountain-cranberry, with a frequency of 98% and a cover of 5%. Blueberry is next with 85% frequency and .1% cover, followed by Labrador-tea with 35% frequency and 1% cover. The others have both low frequency and cover values.

Numerous herb species are present, but only Calamagrostis spp. (mostly bluejoint), bunchberry, and Mertensia paniculata (Ait.) F. Don (tall bluebell) are common. Their respective frequency values are 68%, 38%, and 32%, and cover values are 1%, .4%, and 1%.

The feathermosses, Hylocomium splendens and Pleurozium schreberi, are both important; however, Hylocomium splendens is the more dominant. It has a frequency of 85% and a cover of 54%, whereas Pleurozium schreberi has a frequency of 38% and a cover of 16%. The ground lichen, Peltigera canina (L.) Willd., and the arboreal lichens, Parmelia spp. and Alectoria spp. which occur on fallen twig litter, are common. They have frequency values ranging from 40-62% and cover values of 1-4%, with Peltigera spp. having the higher values.

Litter was found on every plot with an average cover of 28%. Dead wood is less extensive, with a frequency of 68% and a cover of 4%. Bare soil occurs with a frequency of 8% and a cover of 1%.

9) Black Spruce/Labrador-tea/Equisetum sylvaticum: This community type, which is pictured in figure 12, is most common on the lower and middle north, east, and west-facing slopes but can also occur on the upper



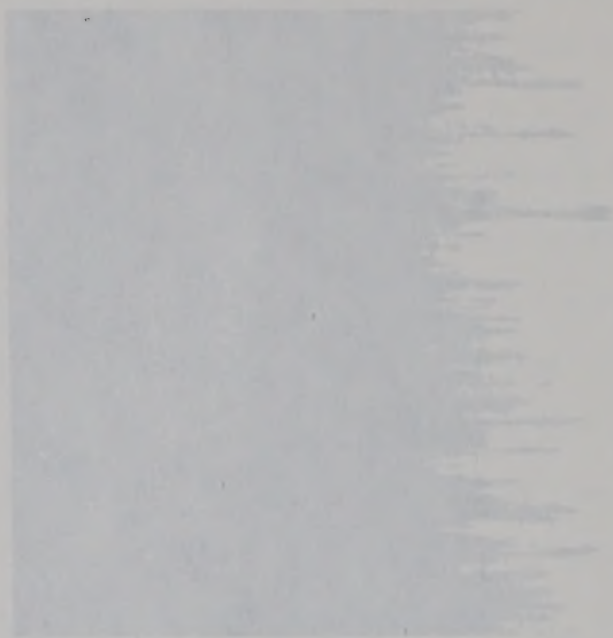
Figure 12.--Black spruce/Labrador tea/
Equisetum sylvaticum community type
occurring on climax black spruce sites
in interior Alaska. The trees in this
stand are about 55 years in age.



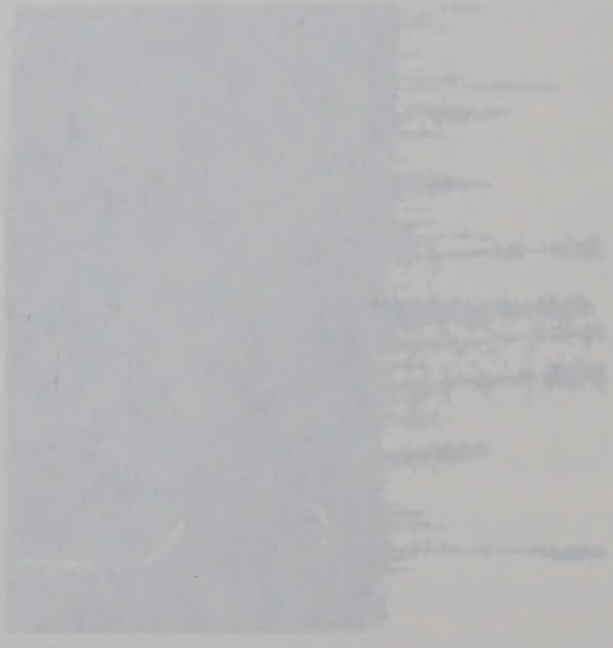
Figure 13.--Black spruce/Narrow-leaf Labrador
tea/Sphagnum community type occurring on climax
black spruce sites in interior Alaska. The trees
in this stand are of two ages, 60 years and 220
years. Note the recently drained bog pond in the
foreground.

Introduction

The purpose of this study is to investigate the effects of the proposed changes on the system. The study is divided into two main parts: a theoretical analysis and an empirical study. The theoretical analysis is based on the principles of the system and the proposed changes. The empirical study is based on the results of the experiments conducted on the system.



The results of the theoretical analysis show that the proposed changes have a significant effect on the system. The theoretical analysis is based on the principles of the system and the proposed changes. The empirical study is based on the results of the experiments conducted on the system.



slopes. Commonly the slope gradient ranges between 5-20%. The organic layer is deeper, (23 cm or 9.1 in) than any of the types already described. Soil temperatures remain low throughout the summer. In September permafrost can be reached at 60 cm (23.6 in). Sixty-year-old stands of this type are very common.

The flora of the Black Spruce/Labrador-tea/Equisetum sylvaticum type is rich, averaging 38 species per stand. The average density for all tree species totals 1,682 trees, 1,118 saplings, and 20,250 seedlings per hectare; while the average density for all willow species totals 1,000 stems/ha, and the average density for all non-willow tall shrub species totals 8,126 stems/ha. The average percent cover values total 44.6 for low shrubs, 12.7 for herb, 90.2 for moss, and 14.9 for lichen species.

The type is nearly pure black spruce but an occasional birch sapling is found. Numbers of black spruce trees average 1,700/ha, saplings 1,100/ha and seedlings 20,200/ha. In 70-year-old stands the trees average 10.6 cm (4.2 in) dbh.

The tall shrub layer is not well developed. Betula glandulosa Michx. (resin birch) is common, and Salix planifolia Pursh. spp. pulchra (Cham.) Argus (diamondleaf willow) occurs. Resin birch has a frequency of 43% and diamondleaf willow of 18%. The respective densities are 7,400 and 1,000 stems/ha. Rose and green alder are not common but can be found.

The low shrub layer is well developed. Mountain-cranberry, Labrador tea and bog blueberry all occur with frequencies of at least 95% and their respective cover values are 20%, 11%, and 8%. Ledum decumbens (Ait.) Small (narrow-leaf Labrador-tea) and Vaccinium oxycoccus L. (bog cranberry) are also present. Their frequency values are 57% and 37%, respectively,

Commonly the slope gradient ranges between 5-20%. The organic layer is deeper, (22 cm on 8.7 in) than any of the ones already described. Soil temperatures remain low throughout the summer. In September permafrost can be reached at 80 cm (23.6 in). Sixty-year-old stands of this type are very common.

The flora of the Black Spruce/Labrador-Larch/Populus sylvatica type is rich, averaging 38 species per stand. The average density for all tree species totals 1,685 stems, 1,135 seedlings, and 20,250 seedlings per hectare; while the average density for all willow species totals 1,000 stems, and the average density for all non-willow tall shrub species totals 8,155 stems/ha. The average percent cover values total 44.8 for low shrubs, 12.3 for herb, 80.5 for moss, and 14.9 for lichen species. The type is nearly pure black spruce but on occasional birch sapling is found. Hundreds of black spruce stems average 1,500/ha, seedlings 1,100/ha and seedlings 50,200/ha. In 30-year-old stands the trees average 10.8 cm (4.2 in) dbh.

The tall shrub layer is not well developed. Betula glandulosa Michx. (red birch) is common, and Salix glandulosa Michx. ssp. glutinosa (Chen.) Argus (diamondleaf willow) occurs. Red birch has a frequency of 43% and diamondleaf willow of 18%. The respective densities are 7,400 and 1,000 stems/ha. Rose and green alder are not common but can be found. The low shrub layer is well developed. Kousatein-grassberry, Labrador tea and bog bilberry all occur with frequencies of at least 95% and their respective cover values are 20%, 11%, and 8%. Lodus decumbens (Ait.) Small (narrow-leaf Labrador-tea) and Vaccinium oxycoccos L. (bog cranberry) are also present. Their frequency values are 57% and 37%, respectively.

while their cover values are 3% and 1%.

Rubus chamaemorus L. (cloudberry), woodland horsetail, and Calamagrostis spp. (mostly bluejoint) are the dominant herbs, with the former two being the most important. They occur with respective frequencies of 87%, 73%, and 63%, and cover values of 6%, 4%, and 1%.

The moss layer is almost continuous. The following species are listed in order of decreasing frequency: Pleurozium schreberi-87%, Polytrichum spp.-80%, Sphagnum spp.-73%, Hylocomium splendens-60%, and Aulacomnium palustre (Hedw.) Schwaegr-48%. Their respective cover values are 30%, 5%, 27%, 17%, and 8%. Numerous other species also occur. The arboreal lichens, Parmelia spp. and Cetraria pinastri, which grow on the fallen twig litter, are common, as are the reindeer lichens Cladina rangiferina and C. arbuscula. In addition many of the Cladonia species occur, but none of them in large amounts. Cladina rangiferina is the most extensive with 4% cover.

Litter and dead wood are common but not extensive, and occasionally exposed soil is seen.

10) Black Spruce/Narrow-leaf Labrador-tea/Sphagnum spp: This type, which is pictured in Fig. 13, occurs in the wettest black spruce sites. These are most frequently found in the upland valleys and undrained river-bottom areas, but also on north-exposed slopes. Permafrost can be found about 60 cm (23.6 in) below the surface in August. The organic layer is at least 40 cm (15.8 in) thick, and sometimes more than 120 cm (47.2 in). This type is well-developed in 50-130-year-old stands.

The flora of the Black Spruce/Narrow-leaf Labrador-tea/Sphagnum spp. type is moderately rich, averaging 35 species per stand. The average density for all tree species totals 771 trees, 304 saplings, and 8,875

while their cover values are 35 and 15.

Rubus chamaemorus L. (Coutberry), Woodland Horsetail, and Calamagrostis

ssp. (mostly blanfordii) are the dominant herbs, with the former two being

the most important. They occur with respective frequencies of 85%, 75%,

and 85%, and cover values of 65, 45, and 15.

The moss layer is almost continuous. The following species are listed

in order of decreasing frequency: Leucobryum schweizeri-85%, Polypodium

ssp.-60%, Hylocomium splendens-50%, and Andropogon

galeatus (Hedw.) Schwartz-45%. Their respective cover values are 30%,

85%, 55%, 15%, and 85%. Numerous other species also occur. The arboreal

Ferns, Form-115 spp., and Carex flacca, which grow on the fallen

twig litter, are common, as are the redwood Cladonia rangiferina

and C. arbuscula. In addition many of the Cladonia species occur, but

none of them in large amounts. Cladonia rangiferina is the most extensive

with its cover.

Litter and dead wood are common but not extensive, and occasionally

exposed soil is seen.

10) Black Spruce/Narrow-leaf Labrador-tea/Sphagnum spp.: This type,

which is pictured in fig. 13, occurs in the wettest black spruce sites.

There are most frequently found in the upland valleys and undrained river-

bottom areas, but also on north-exposed slopes. Forbushes can be found

about 60 cm (23.6 in) below the surface in August. The organic layer

is at least 40 cm (15.7 in) thick, and sometimes more than 120 cm (47.2

in). This type is well-developed in 50-70-year-old stands.

The flora of the Black Spruce/Narrow-leaf Labrador-tea/Sphagnum spp.

type is moderately rich, averaging 35 species per stand. The average

density for all tree species totals 771 stems, 304 saplings, and 5,575

seedlings per hectare; while the average density for all tall shrubs, including willow, is zero. The average percent cover values are 30 for low shrub, 22.4 for herb, 82.8 for moss and 17.9 for lichen species.

Both black spruce and Larix laricina (Du Roi) K. Koch (tamarack) can be found, but the latter is infrequent. The spruce are somewhat scattered. Their tree, sapling, and seedling densities are 760, 29, and 8,900/ha, respectively. In 60-year-old stands the trees average 5.1 cm (2.0 in) dbh while in 100-year-old stands they average 6.8 cm (2.7 in) dbh.

There are no tall shrubs: however, the low shrub layer is well developed. Narrow-leaf Labrador-tea, mountain-cranberry, and bog blueberry have frequencies of 95-98% and cover values of 10%, 9%, and 4% respectively. Betula nana L. (dwarf arctic birch), Empetrum nigrum L. (crowberry), bog cranberry, and Labrador-tea are also important. Their frequency values are 75%, 67%, 55%, and 33%, respectively, while their cover values are 5%, 6%, and 2%. This was the only community type in which Chamaedaphne cucullata (L.) Moench (leatherleaf) occurs; but it is not abundant.

The herb layer is not extensive. Cloudberry is the most common species, while Carex spp. (sedge) are the most extensive. Their respective frequency values were 98% and 80%, while their cover values were 7% and 12%.

Sphagnum spp., Polytrichum spp. and Pleurozium spp. dominate the moss layer with frequency values of 85%, 77%, and 72%, and cover values of 47%, 9%, and 23%, respectively. Numerous moss and lichen species occur; Cladina arbuscula and Nephroma arcticum (L.) Torss. are the most extensive with 3% cover.

Litter is ubiquitous but not extensive. It's cover value is 13%. Dead wood is common but even less extensive with a cover of 3%. Exposed

seedlings per hectare; while the average density for all tall shrubs, including willow, is zero. The average percent cover values are 38 for low shrubs, 55.4 for herbs, 55.6 for moss and 17.9 for lichen species.

Both black spruce and *Larix laricina* (DuRoi) Koch (Tamarack) can be found, but the latter is infrequent. The spruces are somewhat scattered. Their tree, sapling, and seedling densities are 160, 23, and 6,000/m², respectively. In 50-year-old stands the trees average 2.7 cm (2.0 in) dbh while in 100-year-old stands they average 8.8 cm (3.5 in) dbh.

There are no tall shrubs; however, the low shrub layer is well developed. Narrow-leaf Labrador-tea, mountain-cranberry, and bog bilberry have frequencies of 95-98% and cover values of 10%, 9%, and 4% respectively. *Betula nana* L. (dwarf arctic birch), *Empetrum nigrum* L. (cranberry), bog cranberry, and Labrador-tea are also important. Their frequency values are 35%, 67%, 52%, and 33%, respectively, while their cover values are 5%, 6%, and 2%. This was the only community type in which *Chamaenerion cucullata* (L.) Moench (ladderwort) occurs; but it is not abundant.

The hard layer is not extensive. *C. canadensis* is the most common species, while *Larix* spp. (sedges) are the most extensive. Their respective frequency values were 98% and 90%, while their cover values were 7% and 12%.

Sphagnum spp., *Polytrichum* spp., and *Pleurozium* spp. dominate the moss layer with frequency values of 84%, 75%, and 70%, and cover values of 4%, 9%, and 5%, respectively. Numerous moss and lichen species occur; *Cladonia arbuscula* and *Neohymenium arcticum* (L.) Torii are the most extensive with 3% cover.

Litter is ubiquitous but not extensive. Its cover value is 13%.

Dead wood is common but even less extensive with a cover of 3%. Exposed

soil is rare.

3. Black Spruce-White Spruce Sites. -- The following 4 mature community types (numbered 11-14) were identified as occurring within the mixed spruce climax type: 11) Birch-White Spruce-Black Spruce/Calamagrostis, 12) Black Spruce-White Spruce/Grayleaf Willow/Hylocomium, 13) Black Spruce-White Spruce/ Labrador-tea/Geocaulon/Hylocomium-Pleurozium, and 14) Black Spruce-White Spruce/Lichens. These areas can burn; but because they are cooler and more moist than the white spruce and the better drained black spruce sites, they burn less frequently. This results in the occurrence of older stands.

11) Birch-White Spruce-Black Spruce/Calamagrostis: This community type, which is pictured in Fig. 14, is the warmest of those occurring on mixed spruce sites. It occurs on southernly exposed upland slopes near a source of both black spruce and white spruce seed, and on slopes with gradients of less than 26%. This type is well-developed in 125-year-old stands. The organic soil in these stands is moderately thick, averaging 13 cm (5.1 in). These stands are the coolest of the southernly exposed upland sites. The flora in the Birch-White Spruce-Black Spruce/Calamagrostis type, with an average of 26 species per stand, is poor. The average density for all the tree species totals 827 trees, 19 saplings, 1,800 seedlings per hectare; while the average density for all the non-willow tall shrub species totals 3,750 stems/ha. The average percent cover values total 3 for all low shrub, 7 for all herb, 6 for all moss, and 1 for all lichen species.

Birch trees dominate with a density of 750/ha; however, white spruce occurs (83 trees/ha). Their average dbh's are 14.9 and 20.6 cm (5.9 and

2077 is rare.

3. Black Spruce-White Spruce Sites. -- The following 4 mature commu-

nity types (numbered 11-14) were identified as occurring within the mixed

spruce (line) type: 11) Birch-White Spruce-Black Spruce-Cajuput.

12) Black Spruce-White Spruce-Black Spruce-Willow-Cajuput. 13) Black Spruce-

White Spruce-Black Spruce-Willow-Cajuput. 14) Black Spruce-

Spruce-White Spruce-Cajuput. These areas can burn but because they are

cooler and more moist than the white spruce and the better drained black

spruce sites, they burn less frequently. This results in the occurrence

of older stands.

11) Birch-White Spruce-Black Spruce-Cajuput: This community

type, which is pictured in Fig. 14, is the warmest of those occurring

on mixed spruce sites. It occurs on southerly exposed upland slopes

near a source of both black spruce and white spruce seed, and on slopes

with gradients of less than 20%. This type is well-developed in 125-year-

old stands. The organic soil in these stands is moderately thick, averaging

12 cm (5 in.). These stands are the coolest of the southerly exposed

upland sites. The figure in the Birch-White Spruce-Black Spruce-Cajuput

type, with an average of 26 species per stand, is poor. The average density

for all the tree species totals 827 trees, 19 saplings, 1,800 seedlings

per hectare, while the average density for all the non-willow tall shrub

species totals 2,750 stems/ha. The average percent cover values total

3 for all low shrub, 7 for all herb, 6 for all moss, and 1 for all lichen

species.

Birch trees dominate with a density of 750/ha; however, white spruce

occurs (83 trees/ha). Their average dbh's are 14.9 and 20.6 cm (5.9 and



Figure 14.--Birch-white spruce-black spruce/
Calamagrostis community type occurring on
climax mixed ws-bs sites in interior Alaska.
The birch trees in this stand are about 120
years in age.



Figure 15.--Black spruce-white spruce/Grayleaf willow/
Hylocomium community type occurring on climax mixed
ws-bs sites in interior Alaska. The trees in this
stand (90) are about 100 years in age.

March 10, 1964

Two deep pools in the river bed about 150
yards apart were filled in the morning. Water
temperature 17° Celsius. The stream bed
about 12' - 15' deep, about 10' wide.



March 10, 1964

Two deep pools in the river bed about 150
yards apart were filled in the morning. Water
temperature 17° Celsius. The stream bed
about 12' - 15' deep, about 10' wide.



8.1 in), respectively. Black spruce, which at this stage, are primarily saplings, are slightly outnumbered by white spruce saplings. Their densities are 19 and 32/ha, respectively. An occasional birch sapling can be found. Most of the seedlings are white spruce which have a density of 1,900/ha.

The tall shrub layer is composed largely of green alder though rose can also be found. Green alder has a density of 3,600 stems/ha and a frequency of 40%. Rose has a density of 125 stems/ha and a frequency of 5%.

The low shrub layer is less developed. It is composed of mountain-cranberry and twin-flower; but neither is particularly common or extensive.

Likewise the herb layer is rather sparse. Calamagrostis spp. (mostly bluejoint) has a frequency of 90% and a cover of 5%, and Lycopodium annotinum L. (stiff club moss) a frequency of 40% and a cover of 2%. Only three other herb species occurred and they were rare.

The moss and lichen species occur in small amounts. Hylocomium splendens is the only moss with a cover of more than 1% and it is only 2%.

The litter layer is extensive, covering 94% of the area. Dead wood covers 5% of the area.

12) Black Spruce-White Spruce/Grayleaf Willow/Hylocomium: This community, which is pictured in Fig. 15, occurs on the gentle, lower south-facing slopes where the white spruce and black spruce sites meet and overlap. The organic soils are moderately deep, averaging 18 cm (7.1 in). Frozen ground can be found year around. In August it is within 54 cm (21.3 in) of the surface. The stand age in this type averages 125 years, but ranges from 76 and 176 years. The flora in the Black Spruce-White Spruce/Grayleaf Willow/Hylocomium type is rich, averaging 46 species per

8.1 in), respectively. Black spruce, which at this stage, are primarily seedlings, are slightly out-numbered by white spruce seedlings. Their densities are 19 and 32/m², respectively. An occasional birch seedling can be found. Most of the seedlings are white spruce which have a density of 1,900/m². The call shrub layer is composed largely of green alder though rose can also be found. Green alder has a density of 3,600 stems/m² and a frequency of 50%. Rose has a density of 122 stems/m² and a frequency of 5%.

The low shrub layer is less developed. It is composed of mountain-cranberry and twin-flower; but neither is particularly common or extensive. Likewise the herb layer is rather sparse. *Cajuputifolius* spp. (mostly bluejoint) has a frequency of 93% and a cover of 52%, and *Lycopodium annotinum* L. (stiff club moss) a frequency of 40% and a cover of 52%. Only three other herb species occurred and they were rare. The moss and lichen species occur in small amounts. *Hypnum splendens* is the only moss with a cover of more than 1% and 1% is only 5%. The litter layer is extensive, covering 94% of the area. Dead wood covers 5% of the area.

(2) Black Spruce-White Spruce/Gray/Willow/Hydrocotyle. This community, which is pictured in Fig. 16, occurs on the gentle, lower south-facing slopes where the white spruce and black spruce differ most and over-100. The organic soils are moderately deep, averaging 18 cm (7.1 in). Frozen ground can be found year around. In August it is within 54 cm (21.3 in) of the surface. The stand age in this type averages 125 years, but ranges from 75 and 175 years. The flora in the Black Spruce-White Spruce/Gray/Willow/Hydrocotyle type is rich, averaging 46 species per

stand. The average density for all the tree species totals 3,834 trees, 461 saplings, 10,312 seedlings per hectare; while the average density for all willow species totals 3,563 and for all the non-willow tall shrub species 1,750 stems/ha. The average percent cover values total 15 for all low shrub, 23 for all herb, 87 for all moss, and 12 for all lichen species.

Black spruce dominates the tree, sapling, and seedling strata, though white spruce trees, saplings and seedlings, as well as birch and balsam poplar trees occur. In 76-year-old stands the average tree diameters are 16.4 cm (6.5 in) for balsam poplar, 10.9 cm (4.3 in) for birch, 7.1 cm (2.8 in) for black spruce, and 6.1 cm (2.4 in) for white spruce. The black spruce have an average density of 3,500 trees/ha, 450 saplings/ha, and 10,000 seedlings/ha.

Grayleaf willow and Salix arbusculoides Anderss. (little tree willow) dominate the tall shrub layer, though rose and highbush cranberry also occur. The willows average 2,000 and 1,400 stems per hectare, respectively, and have frequency values of 32% and 25%.

Mountain-cranberry is the most frequently occurring low shrub, while bog blueberry has the most cover. Their respective frequency values are 85% and 15%, and their cover values are 11% and 23%.

The herb layer is composed of small amounts of numerous species but only Calamagrostis spp. (mostly bluejoint) and Equisetum scirpoides Michx. (dwarf scouring-rush) are important. Calamagrostis spp. has a frequency of 72% and a cover value of 3%, while the dwarf scouring-rush has a frequency of 52% and a cover of 16%.

stand. The average density for all the tree species totals 3,504 trees/ha, 10,315 seedlings per hectare; while the average density for all willow species totals 3,563 and for all the non-willow tall shrub species 1,750 stems/ha. The average percent cover values total 15 for all low shrub, 53 for all herb, 87 for all moss, and 15 for all lichen species.

Black spruce dominates the tree, sapling, and seedling strata, though white spruce trees, saplings and seedlings, as well as birch and balsam poplar trees occur. In 15-year-old stands the average tree diameters are 16.4 cm (8.5 in) for balsam poplar, 10.5 cm (4.1 in) for birch, 7.1 cm (2.8 in) for black spruce, and 6.1 cm (2.4 in) for white spruce. The black spruce have an average density of 3,500 trees/ha, 450 saplings/ha, and 10,000 seedlings/ha.

Grayleaf willow and *Salix arbusculoides* Anders. (little tree willow)

dominate the tall shrub layer, though rose and hiphush cranberry also occur. The willows average 5,000 and 1,400 stems per hectare, respectively, and have frequency values of 35% and 15%.

Mountain-cranberry is the most frequently occurring low shrub, while bog blueberry has the most cover. Their respective frequency values are 55% and 15%, and their cover values are 11% and 23%.

The herb layer is composed of small amounts of numerous species but only *Calamagrostis* spp. (mostly bluejoint) and *Equisetum arvense* L. (horsetail) are important. *Calamagrostis* spp. has a frequency

of 55% and a cover value of 3%, while the horsetail has a frequency of 55% and a cover of 10%.

The moss layer is well developed. The most extensive moss is Hylocomium splendens with 95% frequency and 64% cover. Leafy liverworts and Aulacomnium palustre are common, both with frequency values of about 40% and cover values of 7%. Lichens are scattered; those with 2-3% cover are Nephroma spp., Peltigera aphthosa and the Cladonia spp.-Cladina spp. as a group.

The deadfall is mostly buried by the moss. The litter has a cover of 15% and dead wood, 5%.

13) Black Spruce-White Spruce/Labrador-tea/Geocaulon/Hylocomium-Pleurozium: This community type, which is pictured in Fig. 16, occurs most often on poorly drained riverbottom sites but may occur elsewhere. Permafrost is found the year around. In August it is within 40 cm (15.8 in) of the surface. Thaw ponds are common. The organic layer is 18 cm (7.1 in) thick. This type is well-developed in 120-250-year-old stands.

The flora in the Black Spruce-White Spruce/Labrador-tea/Geocaulon/Hylocomium-Pleurozium type is moderately rich, averaging 39 species per stand. The average density for all tree species totals 1,991 trees, 5 saplings, 438 seedlings per hectare; while the average density for all willow species totals 436, and for all non-willow tall shrubs, 10,375 stems/ha. The average percent cover values total 28 for all low shrub, 18 for all herb, 76 for all moss, and 5 for all lichen species.

Black spruce dominate, but white spruce, birch and larch also occur. For black spruce the totals are 1,800 trees/ha, 5 saplings/ha and 400 seedlings/ha; while white spruce averages 200 trees/ha, birch 29 trees/ha, and larch 15 trees per ha. In 250-year-old stands the trees' average dbh are 10.4 cm (4.1 in) for black spruce, 11.4 cm (4.5 in) for white spruce, and 21.6 cm (8.5 in) for larch. In 120-year-old stands the birch

The moss layer is well developed. The most extensive moss is *Hypnum* *repens* with 35% frequency and 65% cover. Leafy liverworts and *Autumnum* *sp.* are common, both with frequency values of about 40% and cover values of 35%. Lichens are scattered; those with 2-3% cover are *Cladonia* *sp.*, *Polyporus* *sp.* and the *Cladonia* *sp.* as a group. The deadfall is mostly buried by the moss. The litter has a cover of 15% and dead wood, 25%.

131 Black Spruce-White Spruce/Larix-Spruce/Hypnum
Forest: This community type, which is pictured in Fig. 15, occurs most often on poorly drained riverbottom sites but may occur elsewhere. *Pinus strobus* is found the year around. In August it is within 40 cm (15.7 in) of the surface. These birds are common. The organic layer is 18 cm (7.1 in) thick. This type is well-developed in 150-250-year-old stands. The floor in the Black Spruce-White Spruce/Larix-Spruce/Hypnum *Forest* type is moderately rich, averaging 39 species per stand. The average density for all tree species totals 7,991 trees/ha, 5 saplings/ha, 438 seedlings per hectare; while the average density for all willow species totals 436, and for all non-willow tall shrubs, 10,335 stems/ha. The average percent cover values total 28 for all low shrub, 18 for all herb, 76 for all moss, and 5 for all lichen species.

Black spruce dominates, but white spruce, birch and larch also occur. For black spruce the totals are 1,800 trees/ha, 5 saplings/ha and 400 seedlings/ha; while white spruce averages 500 trees/ha, birch 28 trees/ha and larch 15 trees per ha. In 250-year-old stands the trees' average dbh are 10.4 cm (4.1 in) for black spruce, 11.4 cm (4.5 in) for white spruce, and 21.8 cm (8.5 in) for larch. In 150-year-old stands the birch

A



B

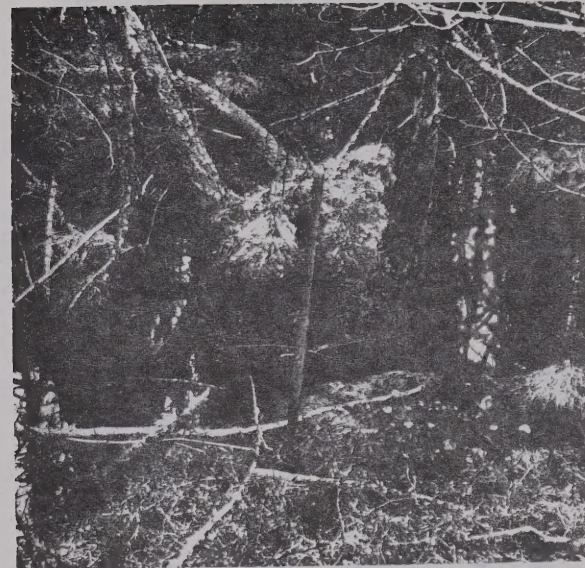


Figure 16.--Black spruce-white spruce/Labrador tea/*Geocaulon*/*Hylocomium*-*Pleurozium* community type occurring on climax mixed bs-ws sites in interior Alaska. A: general view. Trees in this stand are at least 150 years old. B: typical thaw pond found within the stand.

average 8.7 cm (3.4 in) dbh.

Both grayleaf willow and littletree willow occur but neither is common. Rose and green alder dominate the tall shrub layer. Rose has 2,200 stems/ha and a frequency of 50%; while green alder has 8,100 stems/ha and a frequency of 40%.

Mountain-cranberry and Labrador-tea dominate the low shrub layer. Their cover values are 17% and 6%, while their frequency values are 100% and 65%, respectively.

The most extensive herb species are Calamagrostis spp. (mostly bluejoint) and Geocaulon lividum, which occur with 85% and 80% frequencies and both with a cover of 5%. Woodland horsetail is next most common, followed by dwarf scouring-rush, with frequency values of 52% and 42%, and cover values of 4% and 2%, respectively.

The only two mosses which are extensive are Hylocomium splendens and Pleurozium schreberi. These feathermosses have frequencies of 90% and 55%, and cover values of 43% and 27%, respectively. The arboreal lichens occur frequently on the twig litter but in small amounts while ground lichens occur infrequently.

Litter has a 22% cover, while dead wood has only 5%.

14) Black Spruce-White Spruce/Lichens: This community type, which is pictured in Fig. 17, occurs near treeline on north and northeast-facing slopes with gradients of 15-20%. The organic layer is very shallow and the mineral soil quite stony. This type is well-developed in stands with ages ranging from 60 to 150 years.

The flora in the Black Spruce-White Spruce/Lichen type, with an average of 46 species per stand, is the most diverse of any community type found.

average 8.7 cm (3.4 in) dbh.

Both grayleaf willow and litterbox willow occur but neither is common. Rose and green alder dominate the tall shrub layer. Rose has 2,500 stems/ha and a frequency of 50%; white green alder has 8,100 stems/ha and a frequency of 40%.

Mountain-cranberry and Labrador-tea dominate the low shrub layer. Their cover values are 1% and 6%, while their frequency values are 100% and 65%, respectively.

The most extensive herb species are *Calamagrostis* spp. (mostly bluejoint) and *Geocaulon lividum*, which occur with 55% and 80% frequencies and both with a cover of 5%. Woodland horsetail is next most common, followed by dwarf scouring-rush, with frequency values of 55% and 45%, and cover values of 4% and 5%, respectively.

The only two mosses which are extensive are *Hypnum splendens* and *Pleurozium schreberi*. These feathermosses have frequencies of 90% and 55%, and cover values of 45% and 57%, respectively. The arbutus lichens occur frequently on the two litter but in small amounts while ground lichens occur infrequently.

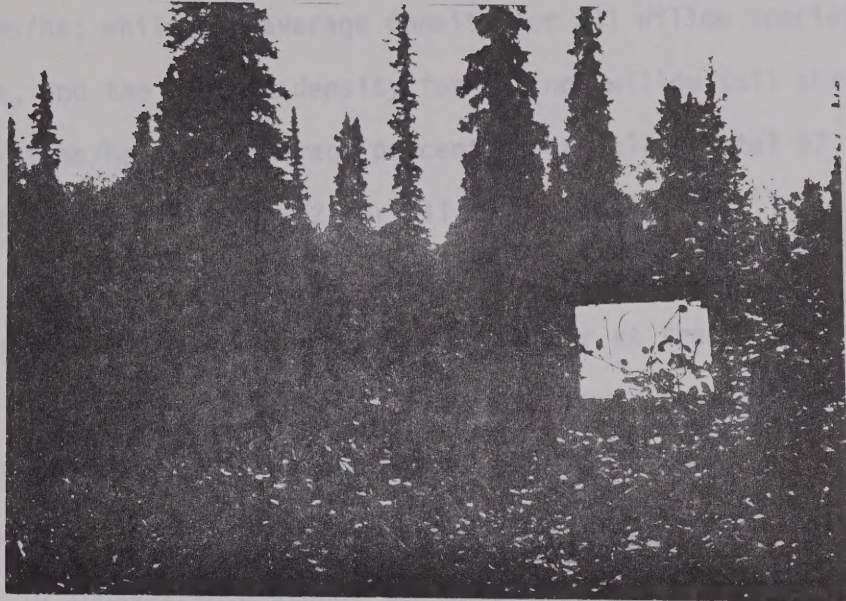
Litter has a 55% cover, while dead wood has only 5%.

14) Black Spruce-White Spruce/Lichen: This community type, which

is pictured in Fig. 17, occurs near tree line on north and northeast-facing slopes with gradients of 15-20%. The organic layer is very shallow and the mineral soil is quite stony. This type is well-developed in stands with ages ranging from 60 to 150 years.

The flora in the Black Spruce-White Spruce/Lichen type, with an average of 65 species per stand, is the most diverse of any community type found.

A



B

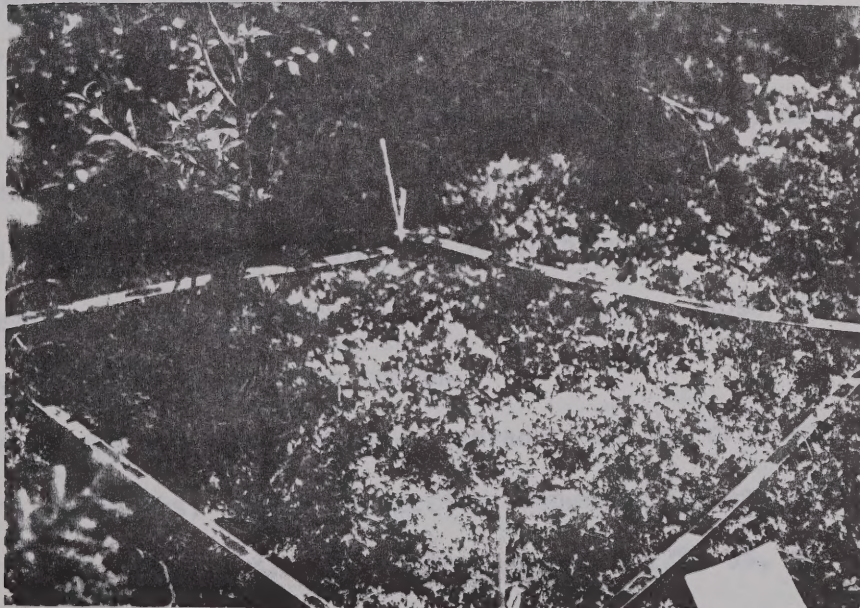


Figure 17.--Black spruce-white spruce/Lichen community type occurring on climax mixed ws-bs sites in interior Alaska. A: general view; the trees are over 100 years old. B: close-up of lichens which are extensive.



Figure 17.--Black spruce-white spruce forest community type occurring on climate mixed wet sites in Interior Alaska. A: General view; the forest are over 100 years old. B: Close-up of debris which are extensive.

The average density for all tree species totals 403 trees, 130 saplings, 7,150 seedlings/ha; while the average density for all willow species totals 3,938 stems/ha, and the average density for all non-willow tall shrubs totals 21,374 stems/ha. The average percent cover values total 57 for all low shrubs, 5 for all herb, 52 for all moss, and 41 for all lichen species.

Black spruce, white spruce and birch all occur as trees, saplings and seedlings; but the birch are rare. Average spruce densities are 259 black spruce trees, 139 white spruce trees, 77 black spruce saplings, 51 white spruce saplings, 7,000 black spruce seedlings, and 50 white spruce seedlings/ha. In 100-year-old stands the trees average 8.9 cm (3.5 in) in diameter for white spruce, 7.8 cm (3.1 in) for black spruce and 3.5 cm (1.4 in) for birch.

Willows occur with a density of 3,900 stems/ha; but only diamondleaf willow was identified to species. It occurred with only 188 stems/ha. The most dominant tall shrub, however, is resin birch which has a density of 19,812 stems/ha and a frequency value of 72 percent. Rose (32% frequency and a density of 1,500/ha) is also common.

Mountain-cranberry, bog blueberry, Labrador-tea and crowberry are all important low shrubs. Their respective frequency values are 100%, 98%, 65%, and 42%; while their cover values are 24%, 23%, 5%, and 4%.

The herb layer is sparse. Calamagrostis spp. (mostly bluejoint), with a frequency of 58% and 2% cover, is the most common.

In contrast, the moss and lichen species are well represented. The mosses, Polytrichum spp., Pleurozium schreberi, Hylocomium splendens, Dicranum spp., and Aulacomnium palustre, occur with frequencies of 90%

The average density for all tree species totals 405 trees, 130 saplings, 1,150 seedlings; while the average density for all willow species totals 3,938 stems/m², and the average density for all non-willow tall shrubs totals 51,315 stems/m². The average percent cover values total 53 for all low shrubs, 5 for all herbs, 55 for all moss, and 41 for all lichens species.

Black spruce, white spruce and birch all occur as trees, saplings and seedlings; but the birch are rare. Average species densities are 269 black spruce trees, 135 white spruce trees, 77 black spruce saplings, 51 white spruce saplings, 7,001 black spruce seedlings, and 58 white spruce seedlings/m². In 100-year-old stands the forest average 8.9 cm (3.5 in) in diameter for white spruce, 5.4 cm (2.1 in) for black spruce and 3.5 cm (1.4 in) for birch.

Willows occur with a density of 3,938 stems/m², but only *Salix glauca* willow was identified in species. It occurred with only 168 stems/m². The most abundant tall shrub, however, is *Salix glauca* which has a density of 19,872 stems/m² and a frequency value of 75 percent. *Betula* (30% frequency) and a density of 1,500/m² is also common.

Mountain-creaberry, bog viburnum, Labrador-tea and strawberry are all important low shrubs. Their respective frequency values are 100%, 98%, 95%, and 45%; while their cover values are 14%, 13%, 5%, and 6%. The herb layer is sparse. *Calluna vulgaris* spp. (mostly blueberry) with a frequency of 55% and 5% cover, is the most common. In contrast, the moss and lichen species are well represented. The mosses, *Polypodium* spp., *Pleurozium schreberi*, *Hypnum* spp., *Acidum* spp., and *Autumnum palustre*, occur with frequencies of 30%

for Polytrichum spp. and decreasing to 40 for Aulacomnium palustre. Their cover values are 5%, 23%, 12%, 6%, and 3%, respectively. Lichens abound, with the reindeer lichens, Cladina rangiferina and C. arbuscula, Cetraria cucullata (Bell.) Ach., Cetraria islandica, Peltigera aphthosa, and Peltigera canina (L.) Willd., all occurring with frequencies greater than 40% and cover values of 4-9%. Cetraria richardsonii Hook. is the only lichen species that is unique to this community type. It occurs with a 36% frequency and 1% cover.

Litter has 26% cover and dead wood has 15 percent.

C. Post-Burn Successional Community Types Occurring on Upland Sites in Interior Alaska.

In the previous section I defined 14 mature community types -- 4 occurring on white spruce climax sites, 6 on black spruce climax sites, and 4 on mixed spruce sites. These mature types represent the culmination of numerous successional stages that have followed disturbance, especially fire. For each of the mature climax community types there is a distinct pattern of succession. Therefore I will first describe in general terms each of these stages as a distinct unit for a given climax type, then I will point out the patterns of change that occur as one of these stages passes into the next stage. In addition, I will comment on how the succession in each of the specific community types differs from this generalized pattern. This generalized description uses the average of all values for each species that occur within a given set of stands, i.e. all the stands in a given age group and occurring on the same site type.

for Polytrichum spp. and decreasing to 45 for Aulacomnium palustre. Their cover values are 57, 53, 52, 51, and 35, respectively. Lichen sp. with the highest frequency, Cladonia recurvata and C. arbuscula, Lecanora conspicua (Bolt.), Ach., Lecanora islandica, Peltigera aphanopetala, and Peltigera canina (L.) Willd., all occurring with frequencies greater than 40% and cover values of 4-9%. Lecanora richardsonii Hook. is the only lichen species that is unique to this community type. It occurs with a 35% frequency and 1% cover.

Litter has 56% cover and dead wood has 15 percent.

C. Post-Burn Successional Community Types Occurring on

Island Sites in Interior Alaska

In the previous section I defined 14 mature community types -- 6 occurring on white spruce climax sites, 6 on black spruce climax sites, and 2 on mixed spruce sites. These mature types represent the culmination of numerous successional stages that have followed disturbance, respectively. For each of the mature climax community types there is a distinct pattern of succession. Therefore I will first describe in general terms each of these stages as a distinct unit for a given climax type, then I will point out the patterns of change that occur as one of these stages passes into the next stage. In addition, I will comment on how the successional pattern of the specific community types differs from this generalized pattern. This generalized description uses the average of all values for each species that occur within a given set of stands, i.e., all the stands in a given age group and occurring on the same site type.

1. Generalized Succession Occurring on White Spruce Sites. -- The twenty-nine post-burn stands analyzed fell into five groups. Each group corresponded to one distinctive stage in the successional sequence. From youngest to oldest they are 1) moss-herb-seedling stage (1-5 years), 2) willow shrub stage (6-25 years), 3) dense hardwood stage (26-50 years), 4) mature aspen and thinning birch stage (51-100 years), and 5) mature birch and white spruce climax stage (>100 years). No recently burned stands on white spruce sites were encountered. The youngest stand that occurred on white spruce sites which we studied was 4 years, while the oldest was about 270 years old. Change is continuous but variable in speed; thus each stage may occur at slightly different ages than indicated. Throughout the following discussion it may be helpful to refer to Table 4 which summarizes much of what is discussed.

1) Moss-Herb-Seedling Stage (1-5 post-burn years): The vegetation at this stage (see figure 18) is just getting established. An average of 21 species occur. The more important species, litter, and organic soil depth will be described.

These stands are open. Post-fire trees do not yet exist. If trees occur, they have survived the fire. Sucker saplings of both aspen and birch may be common. Aspen suckers average over 3,000 stems/ha (Table 4). Similar figures can be expected for birch. Tree seedlings are even more numerous, with average densities of 115,300 (birch) and 20,200 (aspen), 150 (white spruce), 200 (black spruce), and 40 (balsam poplar)/ha. The spruce mostly occur near timberline on the higher elevation sites. The hardwoods occur with frequencies of about 70% (birch) and 60% (aspen) are common; while the spruce, with frequency values of about 10% (white

Generalized Succession Occurring on White Spruce Sites. -- The

Twenty-nine post-burn stands analyzed fell into five groups. Each group corresponded to one distinctive stage in the successional sequence, from youngest to oldest they are: 1) moss-horn-seedling stage (1-5 years), 2) willow shrub stage (6-25 years), 3) dense herb-out stage (26-50 years), 4) mature aspen and shining birch stage (51-100 years), and 5) mature birch and white spruce climax stage (>100 years). No recently burned stands on white spruce sites were encountered. The youngest stand that occurred on white spruce sites which we studied was 4 years, while the oldest was about 270 years old. Change is continuous but variable in speed; thus each stage may occur at slightly different ages than indicated. Throughout the following discussion it may be helpful to refer to Table 4 which summarizes much of what is discussed.

1) Moss-Horn-Seedling Stage (1-5 post-burn years): The vegetation

at this stage (see Figure 1B) is just getting established. An average of 21 species occur. The more important species, litter, and organic soil depth will be described.

These stands are open. Post-fire trees do not yet exist. If trees occur, they have survived the fire. Sucker saplings of both aspen and birch may be common. Aspen suckers average over 2,000 stems/ha (Table 4). Stuntier figures can be expected for birch. Tree seedlings are even more numerous, with average densities of 115,300 (birch) and 20,300 (aspen). 180 (white spruce), 500 (black spruce), and 40 (balsam poplar)/ha. The spruce mostly occur near timberline on the higher elevation sites. The hardwoods occur with frequencies of about 70% (birch) and 60% (aspen) are common while the spruce, with frequency values of about 10% (white

Table 4. Description of the generalized succession pattern occurring on white spruce sites in interior Alaska.

Category	Years-Since-Burn				
	1-5	6-25	26-50	51-100	>100
Number of Stands Surveyed	4	9	5	4	6
Number of Stand Types Represented	2	2	3	2	4
Average Stand Age	5	20	37	55	144
Average Number Species/Stand	21	37	32	31	32
Tree Species -	(Average dbh, % frequency (F), and density (D)/ha)				
<u>Betula papyrifera</u>					
tree dbh (cm)	(22.5) ^{1/}	5.7	8.7(21.6)	12.0(19.5)	19.4
tree freq/den	27/6	58/296	44/596	61/307	65/378
sapling F/D		60/60	20/4	2/3	20/5
seedling F/D	68/115,312	29/3,263	6/771	16/57,063	2/188
<u>Populus tremuloides</u>					
tree dbh (cm)	2.3(17.4)	3.5(14.8)	8.4(17.0)	12.5	ND ^{2/}
tree freq/den	15/5	38/107	45/515	54/694	2/3
sapling F/D	50/3,113	48/326	23/97		1/1
seedling F/D	62/20,208	36/6,660	21/2,042	15/1,594	3/281
<u>Picea glauca</u>					
tree dbh (cm)		5.2(9.9)	7.6	11.4	25.8
tree freq/den		19/114	5/29	5/15	71/318
sapling F/D		20/22	8/4	4/4	42/15
seedling F/D	9/146	33/4,025	1/21	4/157	12/1,177
<u>Populus balsamifera</u>					
tree dbh (cm)		ND		12.2	27.0
tree freq/den		(.5)0/1		2/9	1/12
sapling F/D		18/1			4/1
seedling F/D	2/42	11/263	1/21	2/157	
<u>Picea mariana</u>					
tree dbh (cm)	--	--	(10.4)	(13.2)	--
tree freq/den			3/21	1/5	
sapling F/D		1/.2	1/1		15/5

Table 4 continued

Category	1-5	6-25	Years-Since-Burn 26-50	51-100	> 100
Tree Species continued -					
<u>Picea mariana</u>					
seedling F/D	5/188	8/325			
Total Tree Density	11	518	1,161	1,030	711
Total Sapling Density	3,113	409	105	7	26
Total Seedling Density	135,708	14,536	2,855	58,971	1,646
Tall Shrub Species -	(% Freq/Stem Den per ha)				
<u>Salix:</u>					
<u>Salix bebbiana</u>	26/1,396	31/13,032	9/708	18/1,032	
<u>Salix species</u>	27/917	1/12			
<u>Salix glauca</u>		29/7,994			
<u>Salix arbusculoides</u>		20/2,109	7/521		
<u>Salix pulchra</u>			1/21		
Total <u>Salix</u> Density	/2,313	/23,037	/1,250	/1,032	/0
Other -					
<u>Rosa acicularis</u>	14/479	48/7,047	65/5,875	66/10,844	64/12,495
<u>Alnus crispa</u>	8/438	10/1,057	4/312	12/2,313	19/2,094
<u>Rubus idaeus</u>	2/63	12/1,775	5/125		
<u>Viburnum edule</u>		17/4,200	39/10,438	44/18,782	35/7,469
<u>Betula glandulosa</u>		1/94			
<u>Alnus incana</u>					2/115
Total Non-Willow Tall Shrub Density	980	14,173	16,750	31,939	22,173
Low Shrub Species -	(% Frequency/% Cover)				
<u>Vaccinium vitis-idea</u>	25/2	11/2	13/1	26/2	20/2
<u>Arctostaphylos uva-ursi</u>	7/.2	2/.05			
<u>Ledum groenlandicum</u>	4/1	10/1	22/3	11/1	1/.01

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Table 4 continued

Category	Years-Since-Burn				
	1-5	6-25	26-50	51-100	> 100
Low Shrub Species continued -					
<u>Linnaea borealis</u>	4/.02	26/2	29/1	54/7	39/2
<u>Arctostaphylos rubra</u>		8/1			
<u>Vaccinium uliginosum</u>		7/1	3/.2	1/.04	
<u>Shepherdia canadensis</u>		6/2			2/.1
<u>Dryas integrifolia</u>		6/.2			
<u>Ribes triste</u>		4/.05			8/1
<u>Spirea beauverdiana</u>		3/.4		4/.05	3/.3
<u>Potentilla fruticosa</u>		2/.01			
<u>Ledum decumbens</u>		(.05)0/.03			
<u>Empetrum nigrum</u>		(.05)0/.02			
<u>Betula nana</u>		(.05)0/.01			
<u>Ribes species</u>		(.05)0/.01			
Total Low Shrub Cover	3.22	9.78	5.2	10.09	5.41
Herb Species - (% Frequency/% Cover)					
<u>Epilobium angustifolium</u>	90/22	75/3	68/6	58/2	15/.3
<u>Calamagrostis species</u>	41/12	62/8	73/10	34/.5	46/2
<u>Equisetum arvense</u>	14/.1	44/4	43/2	65/13	46/6
<u>Lupinus arcticus</u>	13/1	10/1			
<u>Pedicularis labradorica</u>	10/.2	12/.5	5/.05	6/.1	
<u>Moehringia lateriflora</u>	9/.1	22/1	31/.3	18/.2	14/.2
<u>Pyrola secunda</u>	5/.05	6/.05	6/.04	8/.2	11/.2
<u>Equisetum scirpoides</u>	4/.2	47/2			
<u>Mertensia paniculata</u>	4/.1	23/.12	17/.3	26/1	16/.2
<u>Arctagrostis species</u>	3/.3				
<u>Cornus canadensis</u>	3/.05	18/1	60/7	59/5	31/1
<u>Lycopodium clavatum</u>	3/.03				
<u>Parnassia palustris</u>	3/.02				
<u>Graminae species</u>	1/.2	6/.005	2/.2		(.5)0/.005
<u>Castilleja species</u>		18/.5			
<u>Delphinium glaucum</u>		14/.5	12/1		3/.04
<u>Carex species</u>		12/.3			
<u>Galium borealis</u>		9/.1	7/.1	6/.1	11/.3

Table 4 continued

Category	1-5	6-25	Years-Since-Burn			51-100	> 100
			26-50				
Herb Species continued -							
Herb Unknown		8/.1					1/.01
<u>Polygonum alaskanum</u>		6/.5	3/.1				
<u>Astragalus species</u>		5/.2					
<u>Polemonium acutiflorum</u>		5/.2					
<u>Hedysarum species</u>		5/.1					
<u>Gentiana propinqua</u>		5/.1					
<u>Galium species</u>		4/.04					
<u>Achillea species</u>		4/.03					
<u>Lycopodium complanatum</u>		3/1	6/.4				1/.03
<u>Pyrola asarifolia</u>		3/.1	5/.2		6/1		9/.3
<u>Cnidium cnidiifolium</u>		3/.04					
<u>Equisetum sylvaticum</u>		2/.2	7/.1		8/2		10/2
<u>Rubus chamaemorus</u>		2/.1					
<u>Petasites frigidus</u>		2/.05					
<u>Pyrola species</u>		2/.05			1/.01		(.5)0/.01
<u>Senecio species</u>		2/.04					
<u>Saussurea angustifolium</u>		2/.03					
<u>Stelleria species</u>		2/.02			1/.01		(.5)0/.005
<u>Potentilla species</u>		2/.02					
<u>Silene repens</u>		2/.02					
<u>Boschniakia rossica</u>		2/.02	3/.02				
<u>Adoxa moschatellina</u>		2/.01	2/.01				1/.01
<u>Anemone richardsonii</u>		1/.1					
<u>Pyrola chlorantha</u>		1/.1					5/.1
<u>Eriophorum species</u>		1/.04					
<u>Zygadenus elegans</u>		1/.02					
<u>Geocaulon lividum</u>		1/.005	3/.03		5/.2		50/1
<u>Viola biflora</u>		1/.005	18/.2				
<u>Gymnocarpium dryopteris</u>		1/.005	4/.03				
<u>Actea rubra</u>			2/.1				
<u>Aconitum delphinifolium</u>			2/.02				1/.005
<u>Solidago species</u>			2/.02				
<u>Rubus arcticus</u>			1/.03				
<u>Epilobium species</u>					5/.4		

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Table 4 continued

Category	Years-Since-Burn				
	1-5	6-25	26-50	51-100	> 100
Herb Species continued -					
<u>Pyrola grandiflora</u>				5/.1	(.5)0/.005
<u>Planthera species</u>				2/.04	
<u>Equisetum pratense</u>					12/2
<u>Carex concinna</u>					3/.05
<u>Goodyera repens</u>					3/.03
Total Herb Cover	36.35	25.32	28.25	25.86	15.79
Moss Species -	(% Freq/% Cover)				
<u>Ceratodon purpurea</u>	99/20	46/4	5/.2	1/.01	2/0
<u>Polytrichum species</u>	73/5	18/2	24/2	19/1	9/1
<u>Marchantia polymorpha</u>	13/2	2/.02	3/.02		
Moss, other	19/.3	8/.2	10/.2	26/1	20/1
<u>Pleurozium schreberi</u>	8/.1	24/1	28/4	32/1	27/4
<u>Aulacomnium palustre</u>	8/.05	8/.2	3/.03	5/.2	1/0
<u>Drepanocladus uncinatus</u>	4/.2	12/.2	8/.2	18/.4	14/.5
<u>Hylacomium splendens</u>	2/.02	10/2	4/1	22/2	57/31
<u>Aulacomnium turgidum</u>	2/.005	(.5)0/.05	4/.01		
<u>Dicranum species</u>		(.5)0/.02	13/.5	2/.02	4/.1
Leafy Liverwort species			3/.02	5/.4	
<u>Ptilium crista-castensis</u>			2/.01	1/.01	4/1
<u>Hypnum species</u>				4/.1	(.6)0/.1
<u>Rhytidiadelphus species</u>					2/.2
<u>Mnium species</u>					1/0
Total Moss Cover	27.68	9.69	8.19	6.14	38.9
Lichen and Mushroom Species -	(% Freq/% Cover)				
<u>Peltigera canina</u>	16/2	9/.2	9/1	5/.1	2/.1
<u>Peltigera aphthosa</u>		7/.2		10/.2	4/.05
<u>Peltigera Species</u>	13/1	29/2		1/.002	3/.2
Total <u>Peltigera</u> Cover	3	2.4	1.0	.302	.35

Table 4 continued

Category	1-5	6-25	Years-Since-Burn 26-50	51-100	>100
Lichen and Mushroom Species continued -					
<u>Cladonia alpestris</u>		(.5)0/.005			
<u>Cladonia amaurocraea</u>				10/.1	
<u>Cladina rangiferina</u>			7/.2	6/.2	
<u>Cladina arbuscula</u>				1/.01	
<u>Cladonia-Cladina</u> Species	4/.04	14/.2	16/.2	21/.3	11/.1
Total <u>Cladonia-Cladina</u> Cover	.04	.21	.4	.61	.1
<u>Cetraria cucullata</u>					1/.01
<u>Cetraria</u> species	3/.02	3/.03		11/.11	6/.1
<u>Parmelia</u> species	1/.05	10/.2	5/.05	9/.1	50/1
<u>Usnea</u> species	1/.005	2/.02	2/.01	1/.01	23/.4
<u>Alectoria</u> species		(.5)0/.005	2/.01	1/.01	8/.1
<u>Stereocaulon</u> species			7/.1		(.5)0/.005
<u>Fruticose</u>		7/1	9/.3		
<u>Foliose</u>		1/.01		1/.01	
<u>Crustose</u>		(.5)0/.005			
<u>Mushrooms</u>	12/1	8/.1	7/.1	19/.2	4/.04
Total Lichen Cover	4.12	3.98	1.97	1.36	2.11
Litter -	(% Freq/% Cover)				
Leaf, Twig Litter	100/81	100/81	100/93	100/91	93/58
Deadwood	98/11	85/8	60/5	81/5	79/8
Charred Ground	23/2	1/.01	0	0	0
Bare soil -	12/.2	14/1	0	5/3	0
Depth to Permafrost (cm) -	120	120	120	120	120
Depth of Organic Soil Layer (cm) -	3	7	6	10	12

FOOTNOTES:

1/ relic tree2/ no data

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spruce) and 5% (black spruce), are rare.

Young willows characterize the tall shrub stratum. At this stage only Bebb willow could be identified with certainty. It occurs with an approximate density of 1,400 stems/ha and an average frequency of 25%. Other willows occurred with the same frequency but in fewer numbers -- only 900 stems/ha. Rose, green alder and Rubus idaeus L. var. trigosus (Michx.) Maxim. (American red raspberry) are also present but not common. They each have densities of less than 500 stems/ha.

Mountain-cranberry is the best established low shrub, though Labrador-tea, twin-flower, and Arctostaphylus uva-ursi (L.) Spreng. (bearberry) occur. Mountain-cranberry has a cover of 2% and a frequency of 25%, the rest are just present. (Refer to Table 4 for less important species.)

The herb layer, which has a total cover of 36%, is dominated by fireweed and bluejoint. Their frequency values are near 90% and 40%; while their cover values are around 20% and 10%, respectively. Equisetum arvense Lupinus arcticus S. Wats. (alpine lupine), and Pedicularis lavradorica Wirsing (Labrador lousewort) are the next most common with 10-14% frequencies. Numerous other species also occur (Table 4).

Moss, with a total cover of 28%, appears as a green tinge and is easy to overlook. Ceratodon purpureus (Hedw.) Brid., Polytrichum spp., and the thalloid liverwort, Marchantia polymorpha L. are the most extensive. Their frequency values are about 99%, 70%, and 10%; while their cover values are 20%, 5%, and 2%, respectively. Peltigera species, which occur with a frequency of 29% and a cover of 3%, are the most prevalent lichens.

Litter, dead wood, charred ground and exposed soil are also important. They occur with approximate frequencies of 100%, 98%, 25% and 10%; while

source) and 2 (black spruce), are rare.

Young willows characterize the tall shrub stratum. At this stage

only *Betula* willow could be identified with certainty. It occurs with an

average density of 1,400 stems/ha and an average frequency of 55%.

Other willows occurred with the same frequency but in lower numbers --

only 900 stems/ha. Rose, green alder and *Rubus idaeus* L. var. *fruticosus*

(Michx.) Maxim. (American red raspberry) are also present but not common.

They each have densities of less than 500 stems/ha.

Mountain-cranberry is the best established low shrub, though Labrador-

tea, twin-flower, and *Arctostaphylos uva-ursi* (L.) Spreng. (bearberry)

occur. Mountain-cranberry has a cover of 3% and a frequency of 25%; the

rest are just present. (Refer to Table 4 for less important species.)

The herb layer, which has a total cover of 35%, is dominated by fire-

weed and bluejoint. Their frequency values are near 90% and 40% while

their cover values are around 50% and 10%, respectively. *Equisetum arvense*

Lupinus arcticus S. Wats. (alpine lupine), and *Pedicularis furbushiae*

Misting (Labrador loosestrife) are the next most common with 10-15% frequencies.

Numerous other species also occur (Table 4).

Heath, with a total cover of 25%, appears as a green tinge and is

easy to overlook. *Coronilla nummularia* (Hed.) B.S.P. (bell heath) sp.,

and the whitish *Myrica polymorpha* L. are the most extensive.

Their frequency values are about 95%, 70%, and 10%; while their cover

values are 20%, 5%, and 2%, respectively. *Potentilla* species, which occur

with a frequency of 10% and a cover of 2%, are the most prevalent forbs.

Litter, dead moss, charred ground and exposed soil are also important.

They occur with approximate frequencies of 100%, 95%, 55% and 10%, while

their cover values are 80%, 10%, 2% and .2%, respectively. The organic soil layer is only 3 cm thick.

2) Willow Shrub and Sapling Stage (6-25 post-burn years): This slightly older stage (see Fig. 19) has a diverse flora of 37 species per stand, or more than characterizes any other stage. Small trees are present, birch and aspen being the most common. The former has a frequency near 60%, while the latter near 40%. Tree densities are about 300 (birch), 100 (aspen), 110 (white spruce), and one (balsam poplar) per hectare. The dbh for the trees in 20-year-old stands average 4.8 cm (1.9 in) for birch, 3.3 cm (1.3 in) for aspen, 3.5 cm (1.4 in) for balsam poplar, and 3.4 cm (1.3 in) for white spruce. Birch and aspen also lead the sapling class with frequencies of 60% and 50%, and densities of 60 and 325 saplings per ha, respectively. White spruce, balsam poplar, and occasionally, black spruce may occur (see Table 4). Tree seedlings are numerous; the numbers of hardwood seedlings have decreased while the numbers of spruce have increased over those occurring in the younger stand. Their densities average 6,700 (aspen), 3,300 (birch), 4,000 (white spruce), 300 (black spruce) and 300 (balsam poplar) per hectare.

Willows are the main component of a well-developed tall shrub layer; though rose, green alder, red raspberry, and highbush cranberry are also present. Bebb willow, grayleaf willow and littletree willow have densities of 13,000, 8,000 and 2,100 stems per ha, respectively, and occur with frequencies of 30-20%. Except for rose, which has a frequency of 48%, all other tall shrubs have frequency values that are lower than the lowest willow values. Of the non-willow tall shrub total density of 14,200 stems/ha,

their cover values are 95%, 100%, 95% and 95%, respectively. The organic

soil layer is only 3 cm thick.

5/ Willow Scrub and Sapling Stage (6-25 post-burn years): This slightly

older stage (see Fig. 12) has a diverse flora of 35 species per stand,

or more than characterizes any other stage. Willow trees are present,

which are again being the most common. The former has a frequency near

60%, while the latter near 40%. These densities are about 300 (black),

100 (sage), 100 (white spruce), and one (balsam poplar) per hectare.

The data for the trees in 20-year-old stands average 4.8 cm (1.9 in) for

black, 3.3 cm (1.3 in) for white, 3.5 cm (1.4 in) for balsam poplar, and

5.4 cm (2.1 in) for white spruce. Willow and aspen also form the sapling

class with frequencies of 60% and 50%, and densities of 60 and 50 saplings

per ha, respectively. White spruce, balsam poplar, and occasionally,

black spruce may occur (see Table 4). These seedlings are numerous; the

number of natural seedlings have declined with the number of spruce

have increased over those occurring in the younger stand. Their densities

average 6,700 (sage), 3,300 (black), 4,000 (white spruce), 300 (black)

spruce, and 300 (balsam poplar) per hectare.

Willow are the main component of a well-developed tall shrub layer,

though rose, green alder, red raspberry, and huckleberry are also

present. Small willow, greyleaf willow and tamarack willow have densities

of 13,000, 8,000 and 5,100 stems per ha, respectively, and occur with

frequencies of 30-50%. Except for rose, which has a frequency of 40%,

all other tall shrubs have frequency values that are lower than the lowest

willow values. Of the non-willow tall shrub class density of 14,700 stems/ha.

rose accounts for 7,000 and viburnum for 4,300 stems.

The low shrub layer, with a total cover of 10%, has also developed and expanded with increased age. Twin-flower now has a cover of 2% and a frequency near 25%. Arctostaphylos rubra (Rehd. and Wilson) Fern. (red-fruit bearberry), bog blueberry, buffaloberry, and Labrador-tea occur with 1 to 2% cover and 6-10% frequency. Mountain-cranberry, on the other hand, still has a cover of 2%, but with a frequency of 10%, is not as common as it was in the younger stage. Several additional species also occur (Table 4).

The herbaceous stratum is diverse -- forty-four different species were recorded for this layer, though never did all occur in the same stand. The total cover for the herb layer is 25%. Fireweed and bluejoint still dominate but are less common and extensive than in the earlier post-fire period. Equisetum arvense, alpine lupine, and Labrador lousewort have held their own or increased slightly. Mohringia lateriflora (L.) Fenzl (Grove Sandwort), dwarf scouring-rush, and bunchberry, now occur with frequencies of 18-47% and with cover values of 1-2%. See Table 4 for exact values.

Ceratodon purpureus and Polytrichum spp. are still important. Moss species, however, have lower cover and frequency values than they had in the younger stands; total moss cover is 10%. Marchantia polymorpha, on the other hand, is rare. Apparently this species does not last long when in competition with other moss and herb species. Pleurozium schreberi, and Hylocomium splendens occur with frequencies near 25% and 10%, and cover values of 1% and 2%, respectively. Two Peltigera species (P. canina and P. apthosa) are important lichens. Unidentified species of Cladonia are also present in small amounts (Table 4). The total lichen cover is

from accounts for 1,000 and upwards for 4,100 sites.

The low shrub layer, with a total cover of 10%, has also developed

and expanded with increased age. *Juniperus* now has a cover of 2% and

a frequency near 50%. *Arctostaphylos rubra* (Rend. and Wilson) Fern. (red-true)

leaves, dog blueberry, butylberry, and Labrador-tea occur with 1

to 15 cover and 5-10% frequency. *Myrica* on the other hand,

still has a cover of 2%, but with a frequency of 10%, is not as common

as it was in the younger stage. Several additional species also occur

(Table 4).

The herbaceous stratum is diverse -- forty-four different species

were recorded for this layer, though never did all occur in the same stand.

The total cover for the herb layer is 25%. *Polygonum* and *Plantago* still

dominate but are less common and extensive than in the earlier post-fire

period. *Conium maculatum*, *Althaea*, *Althaea*, and *Althaea* have

held their own or increased slightly. *Myrica* (L.) Forst.

(Grass) *Andropogon*, *Andropogon*, and *Andropogon*, now occur with

frequencies of 15-45% and with cover values of 1-25%. See Table 4 for

exact values.

Geranium *Geranium* and *Polygonum* are still important. Less

species, however, have lower cover and frequency values than they had

in the younger stands; total cover is 10%. *Myrica* *Myrica*

on the other hand, is rare. Apparently this species does not last long when

in competition with other moss and herb species. *Polygonum* *Polygonum*

and *Polygonum* *Polygonum* occur with frequencies near 5% and 10%, and

cover values of 1% and 2%, respectively. Two *Polygonum* species (2. *Polygonum*

and 2. *Polygonum*) are important. Unidentified species of *Polygonum*

are also present in small amounts (Table 4). The total herb cover is

4%. Have frequencies of at least 40% and cover values of 5-10% and are

Litter and dead wood are present and visible. There is now little evidence of charred ground. The organic layer is now around 7 cm (2.7 in) thick.

3) Dense Hardwood Stage (26-50 post-burn years): With the passage of time more saplings have grown into trees, the willows have become less dense, and other, less visible changes have occurred (Figure 20). The flora as a whole has become less diverse, with an average of 32 species per stand.

The hardwood trees are dense. Over 500 trees per ha of both birch and aspen may occur. In 40-year-old stands the dbh of these species range from 7.5-9.7 cm (3.0-3.8 in) and they occur with a frequency of about 45%. Spruce occur, but are not common, and average 8.2 cm (3.2 in) dbh. Saplings and seedlings, mostly birch and aspen, are less numerous than in the younger stands. Refer to Table 4.

Bebb willow and littletree willow still occur but no longer dominate the tall shrub layer. Bebb willow has a density of 700 stems/ha and littletree willow a density of 500 stems/ha. Rose has an average frequency of 65% and a density of 6,000 stems per ha while highbush cranberry has a frequency of about 40% and a density of 10,400 stems/ha.

Of the low shrub species, which have a total cover of 5%, Labrador-tea, twin-flower and mountain-cranberry are important. Except for Labrador-tea, which has increased to a 3% cover, their cover, 1-2%, is about the same as it was on the next younger age group. Refer to Table 4.

Fireweed continues to decrease as the post-burn stand age increases while both bluejoint and bunch-berry continue to increase. These species

Litter and dead wood are present and visible. There is not little

evidence of charred ground. The organic layer is now around 7 cm (2.7

in) thick.

3) Open Hardwood Stage (25-50 post-burn years): With the passage

of time more saplings have grown into trees, the willows have become less

dense, and other, less visible changes have occurred (Figure 20). The

floor as a whole has become less diverse, with an average of 32 species

per stand.

The hardwood trees are dense. Over 600 trees per ha of both birch

and aspen may occur. In 10-year-old stands the top of these species range

from 1.2-2.7 cm (3.0-3.8 in) and they occur with a frequency of about

45%. Spruce occur, but are not common, and average 8.2 cm (3.2 in) dbh.

Saplings and seedlings, mostly birch and aspen, are less numerous than

in the younger stands. Refer to Table 4.

Red willow and black willow still occur but are longer distance

the tall shrub layer. Red willow has a density of 100 stems/ha and black

willow a density of 500 stems/ha. Rose has an average frequency of 55%

and a density of 6,000 stems per ha while alder has a frequency

of about 40% and a density of 10,000 stems/ha.

Of the low shrub species, which have a total cover of 5%, Labrador-

rose, twin-flower and mountain-cranberry are important. Except for Labrador-

rose, which has increased to a 2% cover, their cover, 1-2%, is about the

same as it was on the next younger age group. Refer to Table 4.

Fireweed continues to decrease as the post-burn stand age increases

while both blueberry and huckleberry continue to increase. These species

all have frequencies of at least 60% and cover values of 6-10% and are the most extensive herbs. Equisetum arvense and grove sandwort continue to be common. The total herb cover has reached 28%.

Pleurozium schreberi has become the dominant moss species, though Polytrichum spp. is still common. Pleurozium schreberi has an average cover of 4% while both Polytrichum spp. and Hylocomium splendens have cover values near one percent. Numerous other moss species also are present. The total moss layer has an 8% cover. Peltigera spp. and Cladonia spp. continue to be present; the total lichen cover is 2%. Refer to Table 4.

Litter and deadwood are still evident. The former has a cover around 95% and the latter around 5%. No evidence of charred ground remains and bare soil is not present. The litter layer is still 6-7 cm (2.3-2.7 in) thick.

4) Mature Aspen Stage; Thinning Birch Stage (51-100 post-burn years): During this 50 year period both the densities of trees and the number of plant species which occur are declining. See Figures 4 and 5. The average number of plant species per stand is 31. This is also the period when the break-up of the aspen component begins.

In stands averaging 55 post-burn years of age, the aspen average 700 trees/ha, 0 saplings/ha, and 1,500 seedlings/ha and the trees average 12 cm (4.6 in) in diameter (Table 4). When the aspen trees reach about 70 years in age many of them die. The birch in these same aged stands average 300 trees/ha, 3 saplings/ha, and 57,000 seedlings/ha, and the trees average 16 cm (6 in) in diameter. This is half the number of trees that occurred in the dense tree stage. Perhaps the increase in seedling

all have frequencies of at least 5% and cover values of 5-10% and are the most extensive herbs. *Lobelia spicata* and *Grass* continue to be common. The total herb cover has reached 50%.

Phytolacca schreberii has become the dominant herb species, though *Phytolacca sp.* is still common. *Phytolacca schreberii* has an average cover of 45 while both *Phytolacca sp.* and *Phytolacca schreberii* have cover values near one percent. Numerous other herb species also are present. The total moss layer has an 8% cover. *Phytolacca sp.* and *Lobelia sp.* continue to be present. The total lichen cover is 1%. *Phytolacca sp.*

Liver and *deadwood* are still evident. The former has a cover around 95% and the latter around 5%. The evidence of current ground nesting and bare soil is not present. The lichen layer is still 5-7% on 15-25% thick.

4) Future Aspen Stage: Thinning Birch Stage (50-100 year-old trees)
During this 50 year period both the densities of trees and the number of plant species which occur are declining. See Figures 4 and 5. The average number of plant species per stand is 31. This is also the period when the break-up of the aspen component begins.

In stands averaging 55 post-burn years of age, the aspen average 700 trees/ha, 0 saplings/ha, and 1,500 seedlings/ha and the forest average 15 cm (4.6 in) in diameter (Table 6). When the aspen trees reach about 70 years in age many of them die. The birch in these same aged stands average 300 trees/ha, 2 saplings/ha, and 25,000 seedlings/ha, and the forest average 15 cm (6 in) in diameter. This is half the number of trees that occurred in the dense tree stage. Perhaps the decrease in seedling

numbers reflects the opening up of the tree canopy.

Bebb willow is the only willow species present and, averaging 1,000 stems per ha, is not dense. Rose and highbush cranberry dominate the tall shrub layer with densities near 11,000 and 19,000 stems per ha, respectively.

Twin-flower with a cover of 7% forms more than 2/3 of the low shrub cover, though both mountain-cranberry and Labrador-tea are also important (Table 4).

The herb layer, with a total cover of 26% is dominated by Equisetum arvense and bunchberry. Both occur with frequencies around 60%; the former has a cover of 13%, while the latter has 5%. Fireweed and bluejoint are common but have low cover values (Table 4).

Even though the total moss cover is only 6%, the mosses, Pleurozium spp., Hylocomium splendens, Polytrichum spp., and Drepanocladus spp., are common. Hylocomium splendens, with 2% cover, has the most cover. Lichens are present and, though numerous species occur, their total cover is only 1%.

Litter has an average cover of 90% and the dead wood 5 percent. Bare soil occurs, especially where tree roots have become exposed. The organic layer is now about 10 cm (3.9 in) thick.

5) Mature Birch; Climax White Spruce Stage (> 100 post-burn years): This is the final stage in this sequence of post-fire succession. See Figures 6, 7, and 14. The flora averages 32 species per stand.

Birch and white spruce trees are common; both have densities around 300 trees/ha. The birch tree diameters range from 13.5 cm (5.3 in) dbh in 130-year-old stands to 30.8 cm (12.1 in) in 270-year-old stands; while

numbers reflects the opening up of the tree canopy.

Red willow is the only willow species present and, averaging 1,000

stems per ha, is not dense. Rose and highbush cranberry dominate the

fall shrub layer with densities near 11,000 and 18,000 stems per ha, respec-

tively.

Red-flower with a cover of 7% found more than 5% of the low shrub

cover, though both mountain-cranberry and Labrador-tea are also important

(Table 4).

The herb layer, with a total cover of 20% is dominated by *Equisetum*

arvense and *punctatum*. Both occur with frequencies around 80%; the former

has a cover of 15%, while the latter has 5%. Fireweed and bluejoint are

common but have low cover values (Table 4).

Even though the total moss cover is only 5%, the mosses, *Pleurozia*

repens, *Hylocomium splendens*, *Polytrichum* spp., and *Brachythecium* spp.,

are common. *Hylocomium splendens*, with 5% cover, has the most cover.

Lichens are present and, though numerous species occur, their total cover

is only 1%.

Litter has an average cover of 30% and the dead wood 5 percent.

Barren soil occurs, especially where tree roots have become exposed. The

organic layer is now about 10 cm (3.9 in) thick.

5) Nature Birch: Cline White Birch Stage (>100 post-burn years)

This is the final stage in this sequence of post-fire succession. See

Figures 6, 7, and 14. The types average 35 species per stand.

Birch and white spruce trees are common, both have densities around

300 trees/ha. The birch tree diameter range from 11.5 cm (4.5 in) dbh

in 100-year-old stands to 30.8 cm (12.1 in) in 270-year-old stands; while

the white spruce tree diameters, 14.8-39.9 cm (5.8-15.7 in), are slightly larger. Saplings are not common. Birch seedlings are the least numerous of any stage in this successional sequence process. White spruce seedlings average 1,000/ha (Table 4). Although higher densities occurred during the willow shrub stage, spruce seedlings then had to compete with high numbers of hardwood seedlings. Now they outnumber all other species.

There are no willows. Rose and highbush cranberry dominate the tall shrub layer with a total density of 22,200 stems/ha. The former continues to hold its high density of 12,500 stems/ha, while the latter occurs less frequently and with a lower density than occurred in the next younger stage. Highbush cranberry seems to prefer the aspen stands.

The low shrub layer, which has a total cover of 5%, is dominated by twin-flower, mountain-cranberry, and red currant.

Bluejoint, Equisetum arvense, and bunchberry, which together have 9% cover, account for more than half of the total herb cover of 16%. Geocaulon lividum, Equisetum pratense, and woodland horsetail, each with a cover of 1%, are the next most important species (Table 4).

The moss layer has a total cover of 39% and is dominated by Hylocomium splendens, with a cover of about 30% and a frequency of approximately 60%. However, Pleurozium schreberi, and Polytrichum spp. are also common (cover of 4% and 1%); Ptilium crista-castrensis is less common but has a 1% cover. The tree lichens, Parmelia spp. and Usnea spp., are common on the fallen twig litter. However, these, as well as the ground lichens, have a combined total cover of 2%.

Litter is extensive but much is buried in the moss layer. It has a cover of around 60%. The organic layer averages 12 cm (4.7 in) in thickness.

The white spruce tree diameter, 14.8-28.9 cm (5.8-11.7 in.), are slightly larger. Saplings are not common. Birch seedlings are the least numerous of any stage in this successional sequence process. White spruce seedlings average 1,000/m² (Table 4). Although higher densities occurred during the white spruce stage, spruce seedlings then had to compete with high numbers of hardwood seedlings. Now they outnumber all other species.

There are no willows. Rose and highbush cranberry dominate the tall shrub layer with a total density of 32,200 stems/ha. The former continues to hold its high density of 15,600 stems/ha, while the latter occurs less frequently and with a lower density than occurred in the next younger stage. Highbush cranberry seems to prefer the open stands.

The low shrub layer, which has a total cover of 52, is dominated by twin flower, mountain-cranberry, and red current.

Bluejoint, *Eriophorum angustifolium*, and bunchberry, which together have 82 cover, account for more than half of the total herb cover of 162.

Geocaulon lividum, *Eriophorum angustifolium*, and woodland horsetail, each with a cover of 12, are the next most important species (Table 4).

The moss layer has a total cover of 382 and is dominated by *Hypnum* spp. with a cover of about 302 and a frequency of approximately 60%.

However, *Pleurozia schreberei*, and *Polypodium* spp. are also common (cover of 42 and 12). *Ptilium crista-castorei* is less common but has

a 12 cover. The tree lichens, *Paraphysa* spp. and *Imbricaria* spp., are common on the fallen twig litter. However, these, as well as the ground lichens,

have a combined total cover of 22.

Litter is extensive but much is buried in the moss layer. It has

a cover of about 602. The organic layer averages 15 cm (4.7 in.) in thickness

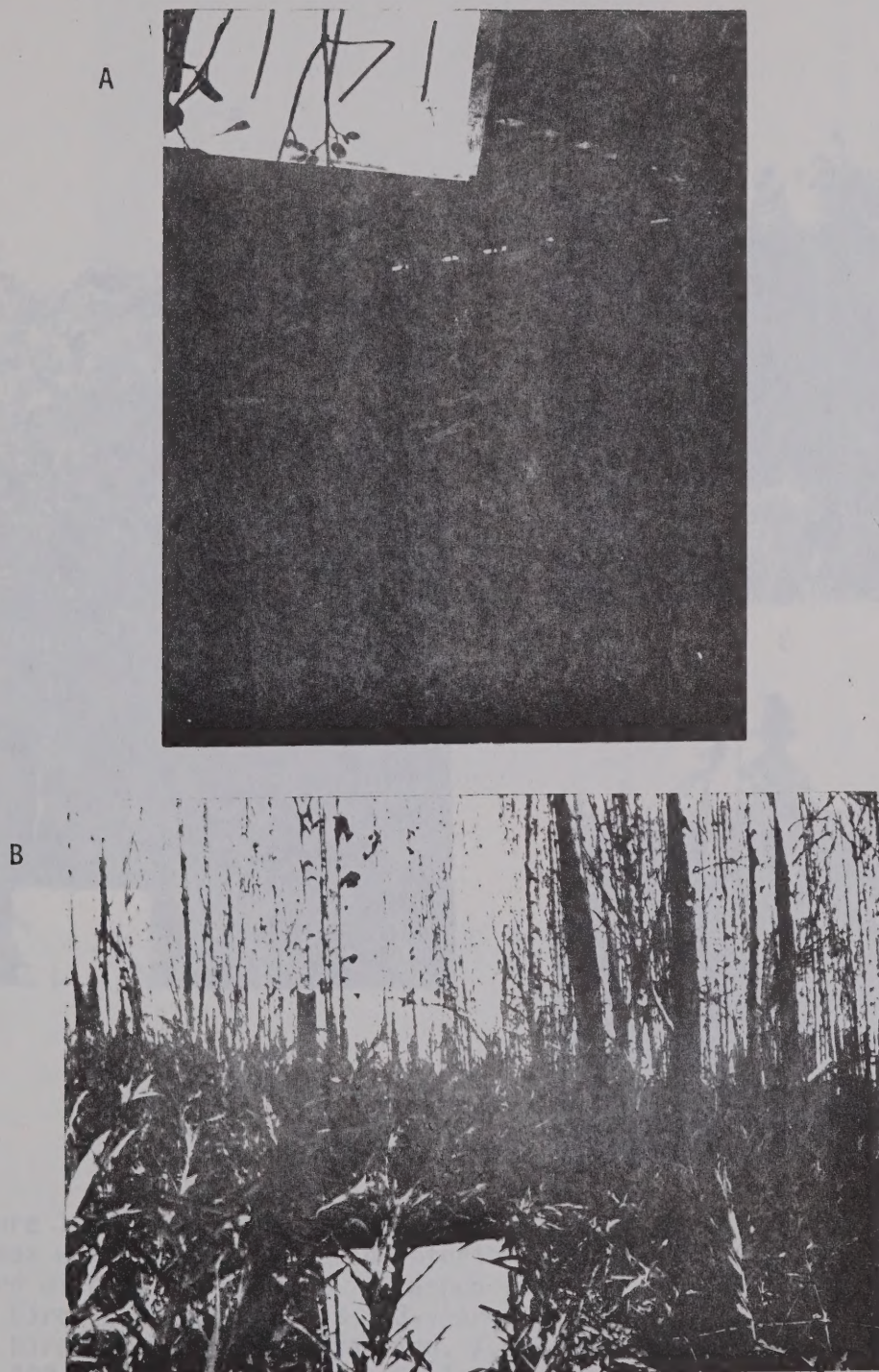


Figure 18.--Moss-herb-seedling stage (1-5 years) on climax white spruce sites in interior Alaska. A: four-year-old post-burn stand with 55,000 aspen and 40,000 birch seedlings/ha. B: four-year-old post-burn stand with 217,000 birch and 1,000 aspen seedlings/ha.



Figure 18.--Moss-forest-seedling stage (1-2 years) on clear
white spruce after in interior Alaska. A: four-year-old post-
burn stand with 25,000 aspen and 10,000 birch seedlings/m².
B: four-year-old post-burn stand with 275,000 birch and 1,000
aspen seedlings/m².

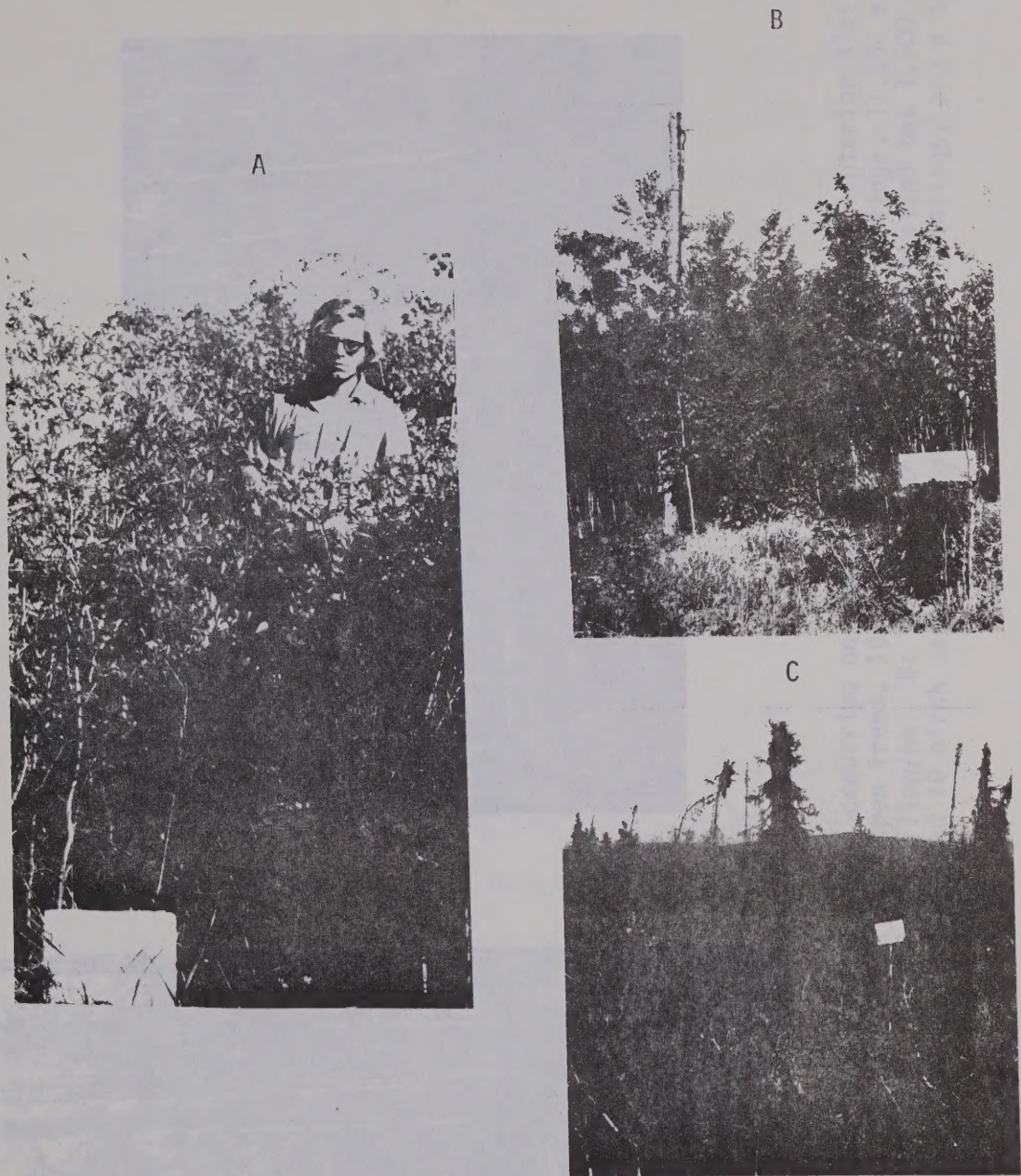
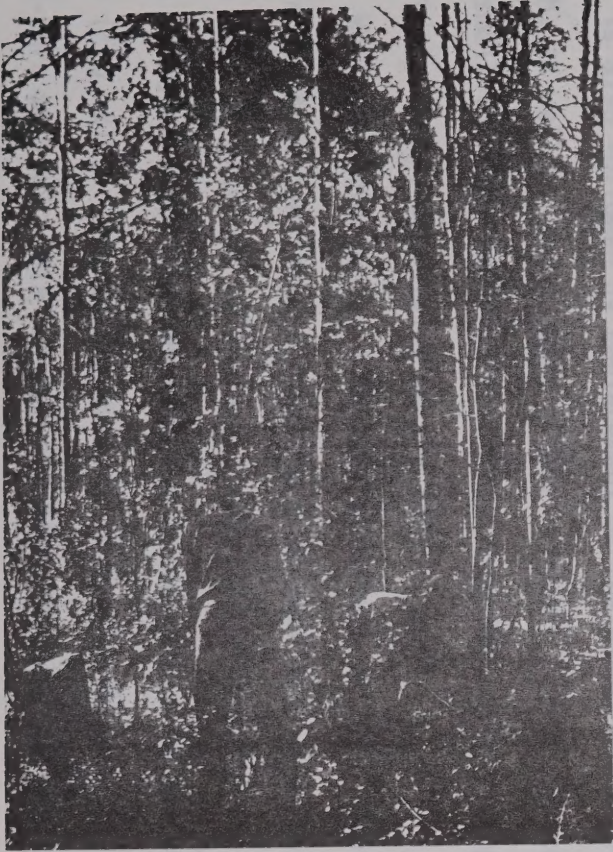


Figure 19.--Willow shrub and sapling stage (6-25 years) occurring on climax white spruce sites in interior Alaska. A: 23-year-old post-burn stand with 83,000 willow, 700 aspen saplings, 10,000 aspen seedlings, and 100 birch seedlings/ha. B: 13-year-old post-burn stand with 100 willow, 100 birch tree, 40 birch sapling, 7,000 birch seedlings, 15 aspen saplings, and 400 aspen seedlings/ha. C: 7-year-old post-burn stand with 5,000 willow, 14,000 resin birch, 0 tree, 0 sapling, 400 spruce seedling, and 200 aspen seedlings/ha.



Figure 10. Willow scrub and sapling stand (5-25 years) occurring on
clay with some silt in interior Alaska. A 15-year-old post-fire
stand with 50,000 willow, 100 spruce seedlings, 10,000 spruce seedlings, and
100 birch seedlings. At 15-year-old post-fire stand with 100 willow,
100 birch, 40 spruce seedlings, 1,000 birch seedlings, 12 spruce seedlings,
and 400 spruce seedlings. At 15-year-old post-fire stand with 5,000 willow,
10,000 spruce birch, 5,000 spruce seedlings, 400 spruce seedlings, and 200 spruce
seedlings.

A



B



Figure 20.--Dense hardwood stage (26-50 years) occurring on climax white spruce sites in interior Alaska. A: this 45-year-old post-burn stand has 500 aspen trees, 100 birch trees, 600 aspen saplings, 11,000 aspen seedlings, 3,000 birch seedlings, and 3,000 willow/ha. B: this 35-year-old post-burn stand has 1,500 birch, 1,000 aspen, and 200 spruce trees, 10 aspen and 10 birch saplings, a total of 1,000 seedlings, and a total of 1,000 willow stems/ha.

2. General Patterns of Change Occurring on White Spruce Sites. -

Thus far the discussion has revolved around the characteristics of each stage separately. A look at Figures 21 and 22 will help to synthesize the effect of time. Each graph in Figure 21 and 22 takes one stratum and shows how the species composition changes as succession proceeds. Graphs 21A - 21E depict the average densities of trees, saplings, seedlings, willows, and non-willow tall shrubs. Note the density scales may differ among the graphs. Graphs 22F -22I depict the average cover values for the low shrubs, herbs, mosses, lichens, and litter. Figure 22K graphs the developing thickness of the organic duff and soil layer. Figure 22L shows the change in floristic diversity.

Hardwoods -- birch and aspen -- are the primary successional tree species on white spruce sites (Fig. 21A). The trees, especially birch, attain their greatest densities during the 26-50 year post-burn period. This is preceded by the maturation of seedlings, and saplings (Fig. 21B,C). This is also followed by replacement of the aspen and a thinning of the birch, as well as an increase in the number of white spruce trees themselves. The small increase in birch seedlings coincides with the opening up of the tree canopy, especially in the aspen stands.

Willows dominate the 1-50 year post-burn period, however they attain their greatest densities during the 6-25 year post-burn period (Fig. 21D). Bebb willow, grayleaf willow and littletree willow are the primary species. Rose shows an almost steady increase in density with the progression of time (Fig. 21E). Highbush cranberry is best developed in the 51-100 year post-burn period. This is when the aspen stands are mature and more open. Red raspberry is an early successional species that seldom persists beyond

2. General Patterns of Change Documented on White Birch Sites

Thus far the discussion has reviewed among the characteristics of each stage separately. A look at Figures 21 and 22 will help to synthesize the effect of time. Each graph in Figure 21 and 22 takes one stratum and shows how the species composition changes as succession proceeds. Graphs 21A - 21E depict the average densities of trees, saplings, seedlings, willows, and red willow tall shrubs. Note the density scales are different among the graphs. Graphs 22A - 22E depict the average cover values for the low shrubs, herbs, mosses, lichens, and lichen. Figure 22K graphs the developing thickness of the organic duff and soil layer. Figure 22L shows the change in floristic diversity.

Handstands — birch and aspen — are the primary successional tree species on white birch sites (Fig. 21A). The trees, especially birch, attain their greatest densities during the 20-50 year post-burn period. This is preceded by the maturation of seedlings, and saplings (Fig. 21B,C). This is also followed by replacement of the aspen and a thinning of the birch, as well as an increase in the number of white spruce trees themselves. The slight increase in birch seedling densities with the opening up of the tree canopy, especially in the aspen stands.

Willows dominate the 1-50 year post-burn period, however they attain their greatest densities during the 5-25 year post-burn period (Fig. 21D). Red willow, gray willow and *Hylocomium* willow are the primary species. Rose shows an almost steady increase in density with the progression of time (Fig. 21E). Highbush cranberry is best developed in the 51-100 year post-burn period. This is when the aspen stands are sparse and more open. Red raspberry is an early successional species that seldom persists beyond

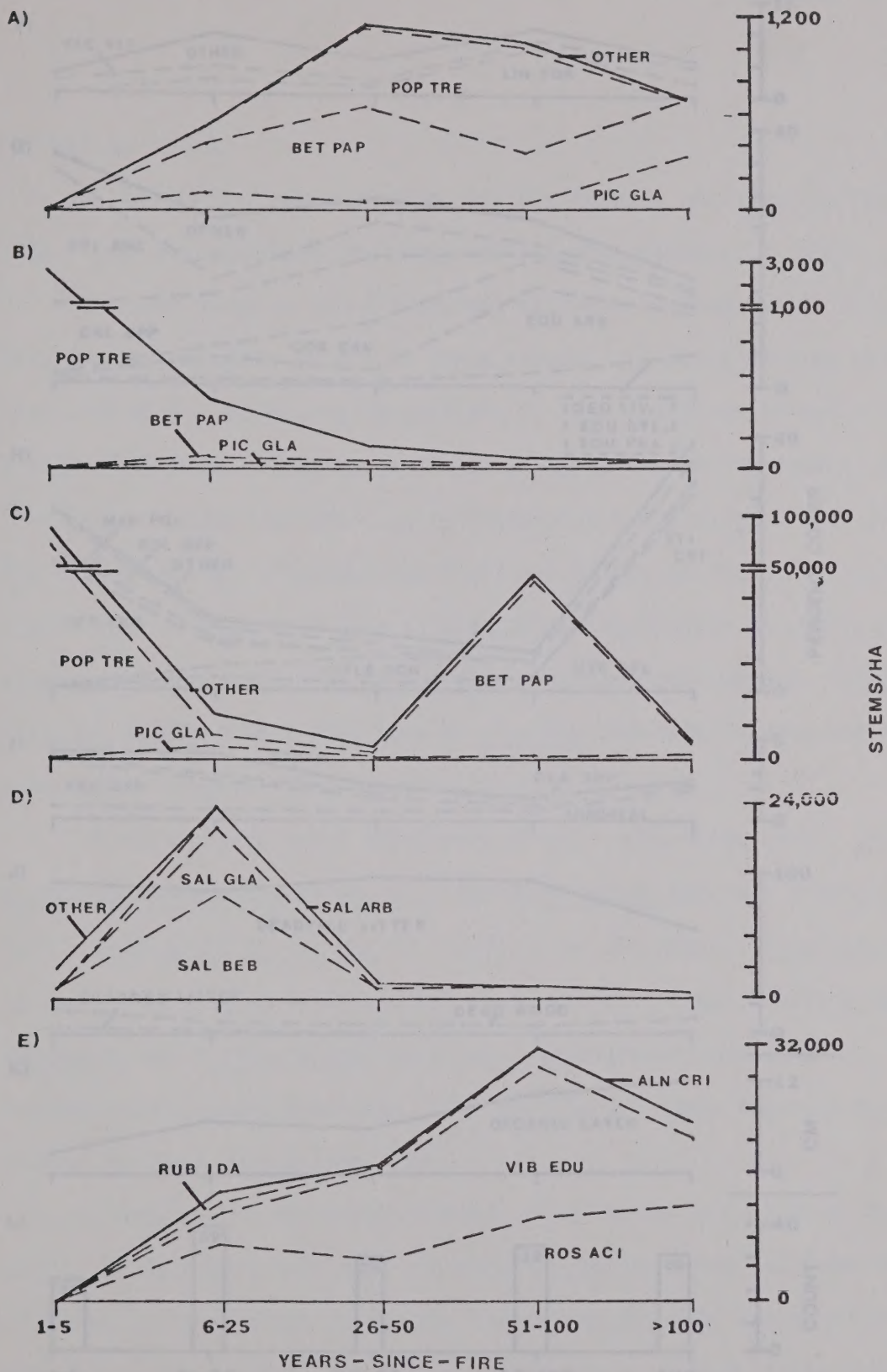


Figure 21.--Graphs showing successional trends on burned white spruce sites. A) Tree densities, B) Sapling densities, C) Seedling densities, D) Willow densities, and E) Non-willow shrub densities. See text for more discussion.

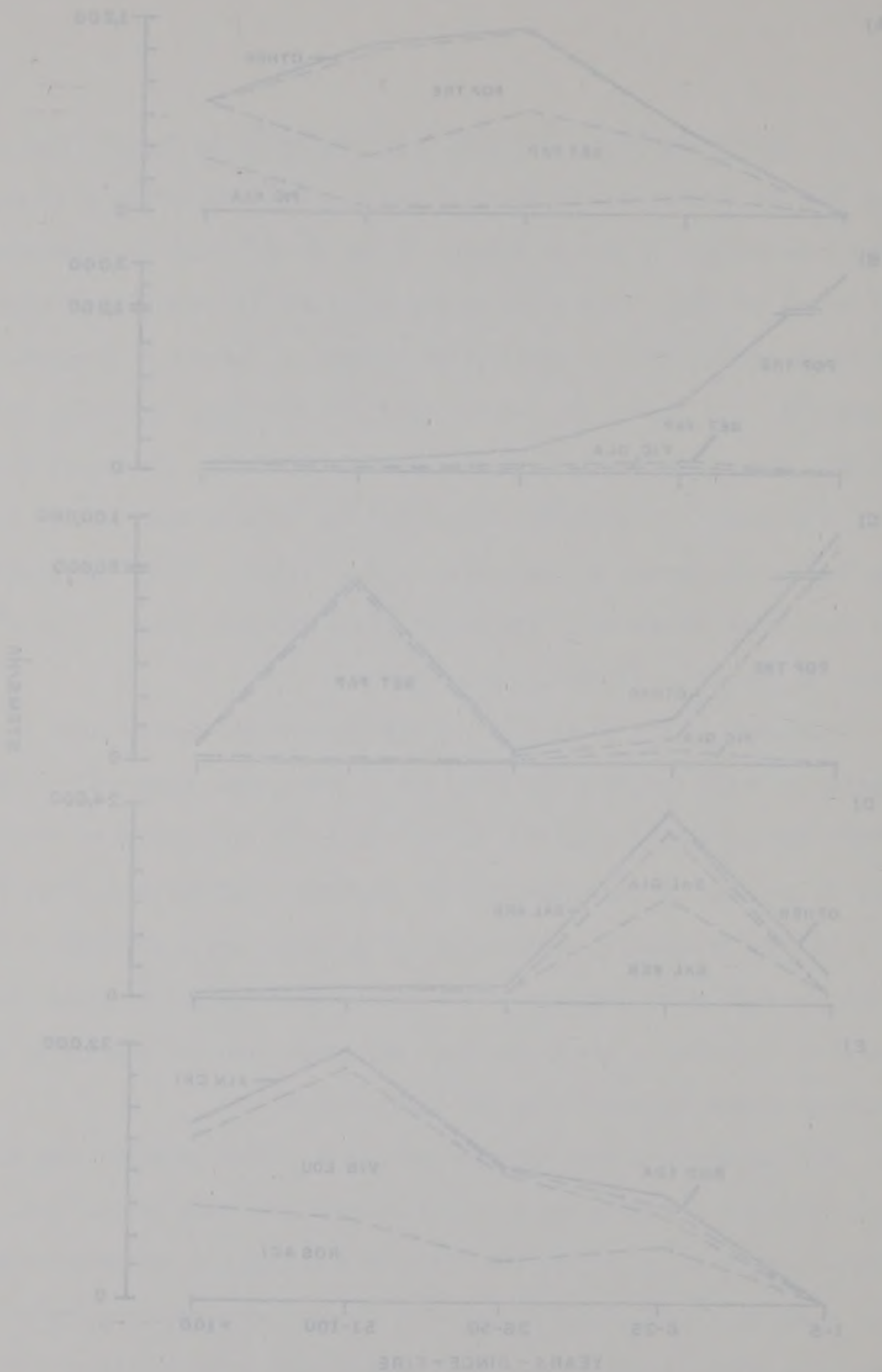


Figure 31. Trends in seedling densities of burned white spruce sites. A) Total densities, B) Seeding densities, C) Seeding densities, D) Willow densities, and E) Non-willow shrub densities. See text for more discussion.

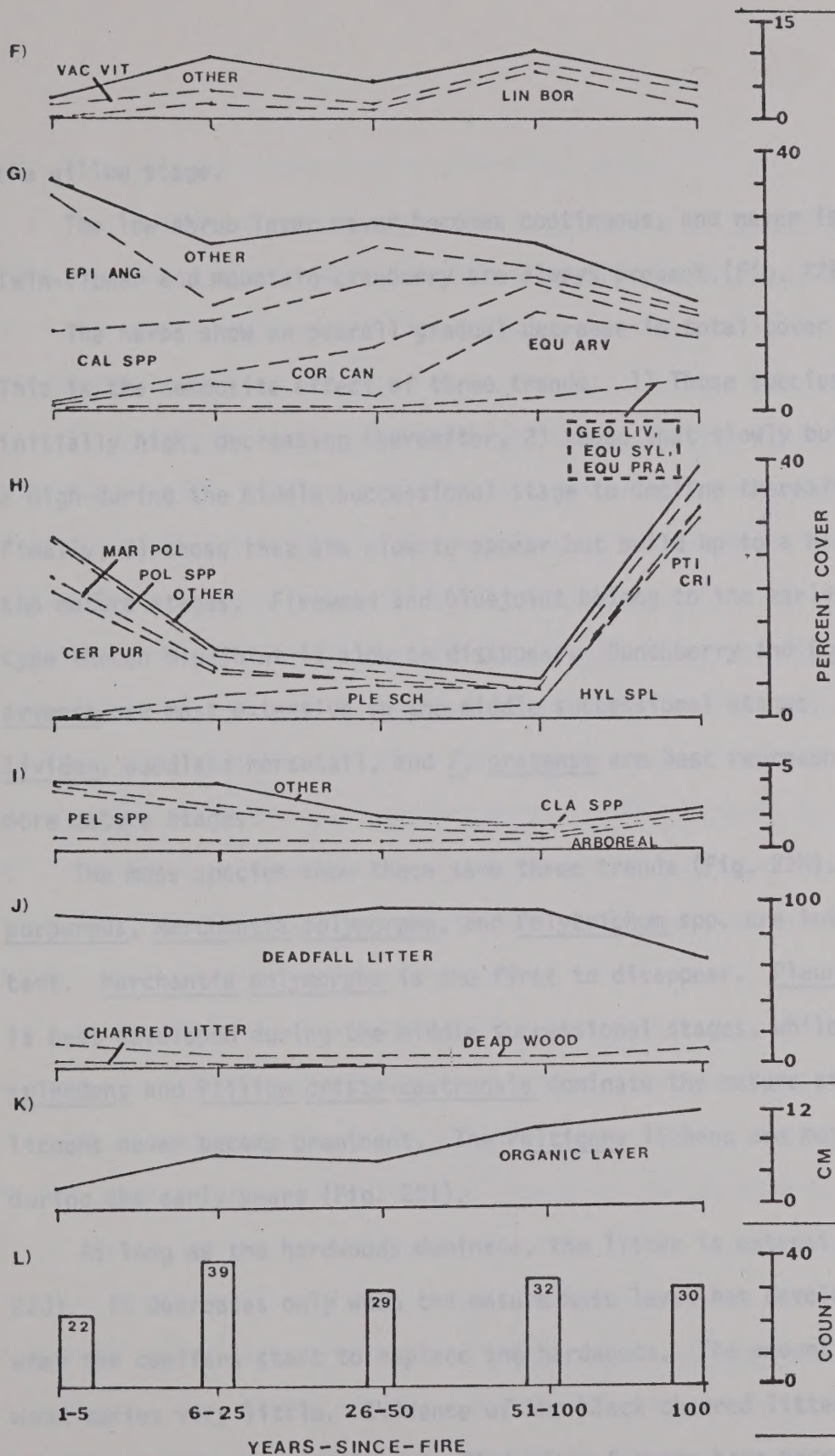


Figure 22.--Graphs showing successional trends on burned white spruce sites (continued). F) Low shrub cover, G) Herb cover, H) Moss and Liverwort cover, I) Lichen and mushroom cover, J) Litter cover, K) Thickness of the organic layer, and L) Average number of plant species per stand. See text for more discussion.

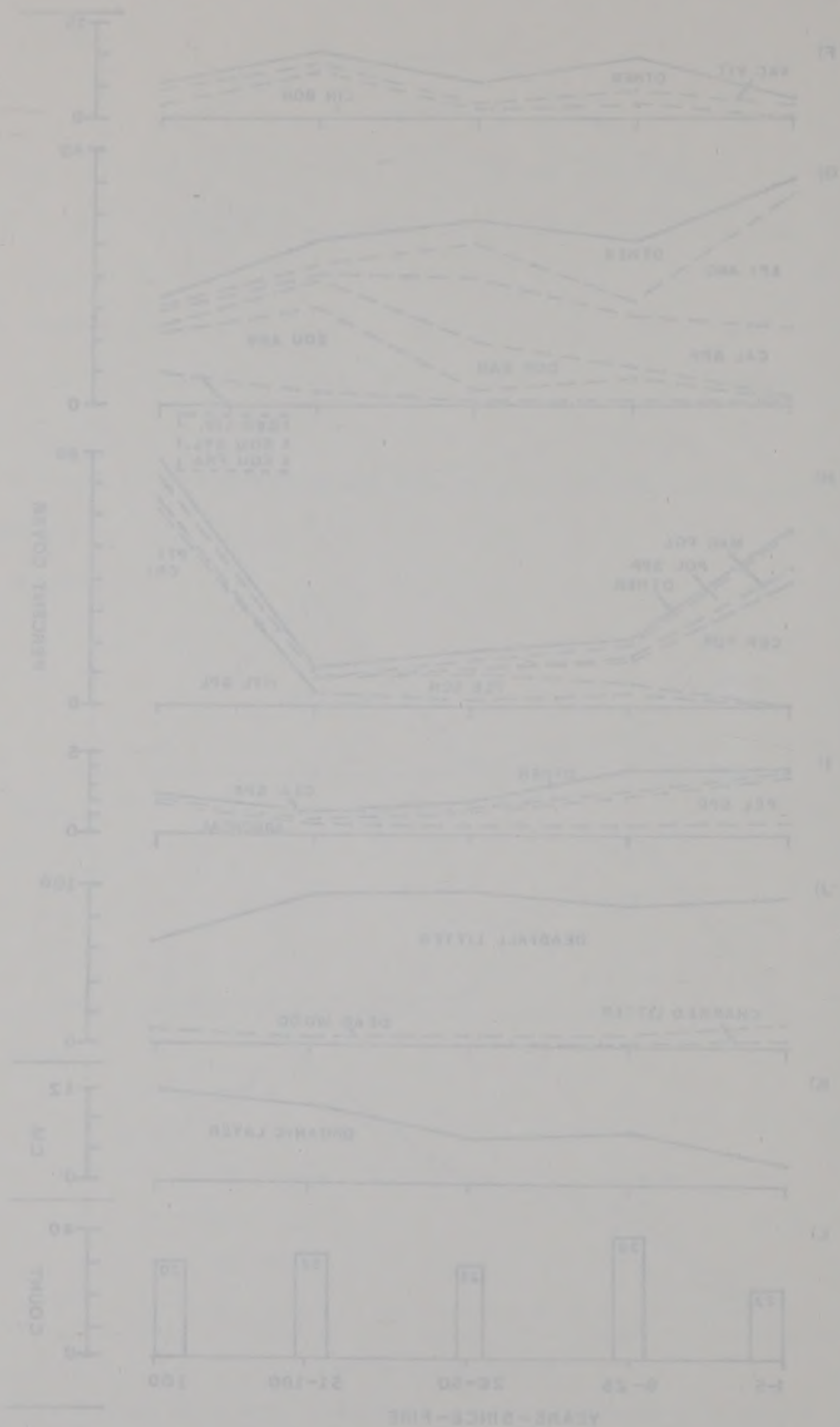


Figure 25--graphs showing successional trends in burned white spruce sites (continued). A) Low shrub cover, B) Herb cover, C) Moss and liverworts cover, D) Lichen and moss cover, E) Litter cover, F) Thickness of the organic layer, and G) Average number of plant species per stand. See text for more discussion.

the willow stage.

The low shrub layer never becomes continuous, and never is well developed. Twin-flower and mountain-cranberry are always present (Fig. 22F).

The herbs show an overall gradual decrease in total cover (Fig. 22G). This is the composite effect of three trends: 1) Those species that are initially high, decreasing thereafter, 2) those that slowly build up to a high during the middle successional stage to decline thereafter and, finally, 3) those that are slow to appear but build up to a high during the mature stages. Fireweed and bluejoint belong to the early successional type though bluejoint is slow to disappear. Bunchberry and Equisetum arvense are most extensive in the middle successional stages. Geocaulon lividum, woodland horsetail, and E. pratense are best represented in the more mature stages.

The moss species show these same three trends (Fig. 22H). Ceratodon purpureus, Marchantia polymorpha, and Polytrichum spp. are initially important. Marchantia polymorpha is the first to disappear. Pleurozium schreberi is best developed during the middle successional stages, while Hylocomium splendens and Ptilium crista-castrensis dominate the mature stage. The lichens never become prominent. The Peltigera lichens are most extensive during the early years (Fig. 22I).

As long as the hardwoods dominate, the litter is extensive (Fig. 22J). It decreases only when the mature moss layer has developed and when the conifers start to replace the hardwoods. The amount of dead wood varies very little. Evidence of the black charred litter which is left by the fire is very hard to find after 6 years have passed. As one would expect, the thickness of the duff and organic soil layer increases

the willow stage.

The low shrub layer never becomes continuous, and never is well developed. Twin-flower and mountain-cranberry are always present (Fig. 22).

The herbs show an overall gradual decrease in total cover (Fig. 22).

This is the composite effect of three trends: 1) Those species that are initially high, decreasing thereafter; 2) those that slowly build up to a high during the middle successional stage to decline thereafter and, finally, 3) those that are slow to appear but build up to a high during the mature stage. Firwood and bluejoint belong to the early successional

type though bluejoint is slow to disappear. Bunchberry and Equisetum are most extensive in the middle successional stages. Baccharis, Juniperus, Woodsia, Woodsia, Woodsia, and E. praeense are best represented in the more mature stages.

The moss species show three trends (Fig. 22). Leucodon, Gymnocarpus, Marchantia polymorpha, and Polypodium spp. are initially important. Marchantia polymorpha is the first to disappear. Plumaria schreb. is best developed during the middle successional stage, while Hypnum, Selaginella, and Ptilium crista-castrensis dominate the mature stage. The lichens never become prominent. The Polypodium lichens are most extensive during the early years (Fig. 22).

As long as the hardwoods dominate, the litter is extensive (Fig. 22). It decreases only when the mature moss layer has developed and when the conifers start to replace the hardwoods. The amount of dead wood varies very little. Evidence of the black charred litter which is left by the fire is very hard to find after 5 years have passed. As one would expect, the thickness of the duff and organic soil layer increases

steadily with the progression of time (Fig. 22K).

3. Specific Succession Patterns Occurring on White Spruce Sites. -

This discussion would not be complete without a few words on how succession in aspen stands, birch stands and white spruce stands each differ from the general pattern.

1) Succession in the Aspen/Highbush cranberry/Twin-flower Type:

Figures 18A, 19A, 20A, and 4 depict what Aspen/Highbush cranberry/Twin-flower stands as they develop through time. Aspen shows a preference for warm white spruce sites. The following species also show this preference: bearberry, twin-flower, shepherdia, Equisetum arvense, alpine lupine, Labrador lousewort, and the Peltigera spp. lichens. Consequently each of these species will occur with much greater frequency, cover, and density values than the generalized pattern depicts. This is especially true of the willows, highbush cranberry, bearberry, shepherdia, alpine lupine, and Labrador lousewort which occur almost entirely in aspen stands. The organic soil layer is slow in developing.

Aspen stands start breaking up when they reach about seventy years of age. This is when the majority of mature trees start falling.

2) Succession in the Birch/Viburnum type: Figures 18B, 19B, 20B, 5, and 14 depict what Birch/Viburnum stands as they develop through time. Birch show a preference for the cooler white spruce sites. The following species also show a trend toward this preference: green alder, red raspberry, beauvered spirea, woodland horsetail, Pleurozium schreberi, and Hylocomium splendens. Fireweed and bluejoint do exceedingly well in the young birch, though this preference disappears with the passage of time. Consequently, each of the above mentioned species will occur with greater frequency,

steadily with the progression of time (Fig. 52A).

3. Specific Succession Patterns Occurring on White Spruce Sites

This discussion would not be complete without a few words on how succession in aspen stands, birch stands and white spruce stands each differ from the general pattern.

1) Succession in the Aspen-Highbush Cranberry/Twin-Flower Type

Figures 18A, 19A, 20A, and 4 depict what Aspen-Highbush Cranberry/Twin-

flower stands as they develop through time. Aspen shows a preference

for warm white spruce sites. The following species also show this preference:

blackberry, twin-flower, shepherds, Equisetum arvense, alpine lupine,

Larix laricina, and the Polygonum spp. Others. Consequently each

of these species will occur with much greater frequency, cover, and density

values than the generalized pattern depicts. This is especially true

of the willows, highbush cranberry, blackberry, shepherds, alpine lupine,

and Larix laricina which occur almost entirely in aspen stands. The

organic soil layer is slow in developing.

Aspen stands start breaking up when they reach about twenty years

of age. This is when the majority of mature trees start falling.

2) Succession in the Birch/Viburnum Type: Figures 18B, 19B, 20B,

and 4 depict what Birch/Viburnum stands as they develop through time.

Birch show a preference for the cooler white spruce sites. The following

species also show a trend toward this preference: green alder, red raspberry,

beavered sedge, woodland horsetail, Polygonum viviparum, and Viburnum

lanceolatum. Firwood and bluejoint do exceedingly well in the young birch

though this preference disappears with the passage of time. Consequently,

each of the above mentioned species will occur with greater frequency,

cover, and/or density values on such cooler sites than the generalized pattern depicts.

Many birch stands start breaking up at about 100 years of age. Others, however, are able to retain their identity for another 50 years.

3) Succession in the White Spruce/Highbush Cranberry/Equisetum arvense and White Spruce/Twin-flower/Equisetum sylvaticum types: Figures 19C, 6 and 7 depict white spruce stands. Young, pure stands of white spruce are rare. More commonly, the white spruce develop in the shade of hardwood species. White spruce trees have a long life span. As a result, most mixed hardwood-white spruce stands eventually become pure white spruce stands. At least two types of mature white spruce community types can develop. Balsam poplar, green alder, thinleaf alder, twin-flower, mountain-cranberry, beauvered spirea, bunchberry, Pyrola asarifolia Michx., (liverleaf wintergreen), woodland horsetail, Ptilium crista-castrensis and Hypnum spp. seem to prefer the cooler riverbottom sites, or those found in the white spruce/twin-flower/woodland horsetail climax type. On the other hand, aspen, highbush cranberry, buffaloberry, Equisetum arvense, fireweed, grove sandwort, and northern bedstraw seem to prefer the warmer upland slopes or those found in the white spruce/highbush cranberry/Equisetum arvense climax type.

cover, and/or density values on such cooler sites than the generalized pattern depicts.

Many birch stands start breaking up at about 100 years of age. Others,

however, are able to retain their identity for another 50 years.

3) Succesion in the White Spruce/Alaskan Cranberry/Toussaint

and White Spruce/Twin-Flower/Toussaint systems: Figures 18C,

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species. White spruce trees have a long life span. As a result, most

mixed hardwood-white spruce stands eventually become pure white spruce

stands. At least two types of mature white spruce community types can

develop. Balsam poplar, green alder, chinquapin alder, twin-flower, mountain-

cranberry, beavered spruce, bunchberry, Pyrola asarifolia Michx., liver-

leaf wintergreen, Pentstemon cristatus, Pentstemon cristatus and Hyssopus

sp. seem to prefer the cooler riverbank sites, or those found in the

white spruce/twin-flower/horseshoe/cornus/cornus/cornus type. On the other

hand, aspen, Rubus crispus, Butcherbush, Toussaint avenae, Fireweed,

grove sandwort, and northern bedstraw seem to prefer the warmer upland

slopes or those found in the white spruce/highbush cranberry/toussaint

avenae climax type.

4. Generalized Successional Stages Occurring on Black Spruce Sites. --

The ninety-three post burned stands occurring on black spruce sites and mixed spruce sites which we analyzed fell into 6 distinctive groups which corresponded to the following 6 stages: 1) newly burned (0 post-burn years), 2) seedling-sucker stage (1-5 post-burn years), 3) willow-shrub stage (6-25 post-burn years), 4) dense hardwood; small diameter black spruce tree stage (26-50 post-burn years), 5) dense black spruce/Pleurozium schreberi stage (51-100 post-burn years) and 6) mature black spruce/feathermoss stage (>100 post-burn years). The reader is reminded that change is continuous but of variable speed so that these stages may occur at slightly different ages than indicated. The youngest stands we studied were newly burned (1-month post-fire) and the oldest were near 175 years. Pure stands of old black spruce are rare, most are reburned before they attain an age of 100 years. The > 100 year-old stands we surveyed were usually mixed white spruce-black spruce. In the following discussion each of these stages will be characterized. It may be helpful to refer to Table 5, which summarizes much of what is discussed below.

1) Newly Burned Stage (1 post-burn years): Stands vary in the degree to which they are burned. Some stands which are only lightly burned have a great deal of green vegetation in them and are best described by the next older stage. Other stands which are intensively burned, as in Fig. 23, are completely blackened above the ground surface; yet even in these areas green sprouts start to appear within two to three weeks of the fire if the fire occurred early in the growing season. These sprouts come mostly from underground plant parts which survived the fire. An average of 10 species will appear. Mostly however, the landscape is black with

4. Generalized Successional Stages Occurring on Black Spruce Sites.

The ninety-three post-burned stands occurring on black spruce sites and mixed spruce sites which we analyzed fell into 6 distinctive groups which corresponded to the following 6 stages: 1) newly burned (0 post-burn years), 2) seedling-sucker stage (1-5 post-burn years), 3) willow-shrub stage (5-25 post-burn years), 4) dense hardwood, small diameter black spruce tree stage (25-50 post-burn years), 5) dense black spruce/ponderosa ponderosa stage (51-100 post-burn years) and 6) mature black spruce/ponderosa stage (>100 post-burn years). The reader is reminded that change is continuous but of variable speed; that these stages may occur at slightly different ages than indicated. The youngest stands we studied were newly burned (1-month post-fire) and the oldest were near 175 years. Pure stands of old black spruce are rare, most are returned before they attain an age of 100 years. The >100 year-old stands we surveyed were usually mixed white spruce-black spruce. In the following discussion each of these stages will be characterized. It may be helpful to refer to Table 2, which summarizes much of what is discussed below.

1) Newly Burned Stage (1 post-burn years): Stands vary in the degree

to which they are burned. Some stands which are only lightly burned have a great deal of green vegetation in them and are best described by the next older stage. Other stands which are intensely burned, as in Fig. 23, are completely blackened above the ground surface, yet even in these areas green sprouts start to appear within two to three weeks of the fire. It the fire occurred early in the growing season. These sprouts come mostly from underground plant parts which survived the fire. An average of 10 species will appear. Mostly however, the landscape is black with

Table 5. Description of the generalized succession pattern occurring on black spruce sites in interior Alaska.

Category	Years-Since-Burn						Fireline 1-6
	0	1-5	6-25	26-50	51-100	>100	
Number of Stands Surveyed	3	31	18	14	13	11	3
Number of Stand Types Represented	2	5	6	5	4	4	1
Average Stand Age	0	4	11	37	68	129	4
Average Number Species/Stand	11.0	22.0	23.0	34.3	35.4	39.4	20.0
Tree Species - (Average dbh, % frequency (F), and density (D) in number/ha)							
<u>Picea mariana</u>							
tree dbh (cm)	-	(5.4)1/	4.3(9.6)	5.6	6.8	7.6	-
tree Freq/Den	0	7/12	17/4	61/1,251	88/1,616	98/1,670	0
sapling F/D	0	6/3	10/4	57/785	97/1,055	78/176	0
seedling F/D	0	27/4,661	31/4,519	33/2,462	76/13,151	54/7,000	62/13,875
<u>Picea glauca</u>							
tree dbh (cm)	-	ND ^{2/}	(11.7)	5.0(10.6)	6.3(14.9)	9.2	-
tree Freq/Den	0	1/2	2/.4	6/27	2/19	20/98	0
sapling F/D	0	0	4/2	15/28	3/4	19/12	0
seedling F/D	0	0	10/996	5/329	2/219	3/88	7/708
<u>Populus tremuloides</u>							
tree dbh (cm)	-	-	5.0(11.8)	7.9	13.0(23.9)	ND	-
tree Freq/Den	0	0	6/38	22/464	27/427	1/5	0
sapling F/D	0	5/602	8/2	2/.4	3/3	0	0
seedling F/D	0	10/9,291	15/1,428	6/462	10/688	0	8/792
<u>Betula papyrifera</u>							
tree dbh (cm)	-	(14.0)	4.8	7.3	8.0(16.1)	9.8	-
tree Freq/Den	0	0	2/1	22/198	9/80	3/13	0
sapling F/D	0	2/2	16/54	14/12	5/5	3/1	0
seedling F/D	0	4/964	15/1,063	2/500	2/78	0/2	17/1,000
<u>Larix laricina</u>							
tree dbh (cm)	-	-	8.3	9.8	-	13.0	-
tree Freq/Den	0	0	2/1	1/2	0	2/5	0
sapling F/D	0	0	(.4)0/.1	0	(.3)0/1	1/3	0
seedling F/D	0	(.2)0/10	2/193	0	0	0	0

Table 5 continued

Category	Years-Since-Burn						Fireline 1-6
	0	1-5	6-25	Forest 26-50	51-100	> 100	
Tree Species continued -							
<u>Populus balsamifera</u>							
tree dbh (cm)	-	-	(7.9)	4.4	-	16.4	
tree Freq/Den	0	0	(.2)0/.2	1 4	0	1/12	0
sapling F/D	0	(.1)0/.4	2/1	1/.2	0	0	0
seedling F/D	0	0	12/2,772	18/1,792	0	0	0
Total Tree Density	0	14	44.6	1,946	2,142	1,803	0
Total Sapling Density		607.4	63.1	1,475.2	1,067	192	0
Total Seedling Density		14,926	10,971	5,509	14,136	7,090	16,375
Tall Shrub Species -							
	(% frequency/density in stems/ha)						
<u>Salix</u>							
<u>Salix planifolia pulchra</u>	10/250	3/385	5/1,435	2/112	4/250	1/38	7/333
<u>Salix species</u>	5/792	8/152	10/949	4/379	(.3)0/23	9/788	52/6250
<u>Salix scouleriana</u>	-	5/2,060	6/441	4/562	2/156		18/833
<u>Salix bebbiana</u>		2/164	30/5,861	6/350	3/107	6/412	
<u>Salix glauca</u>		1/188	10/1,875	3/200		8/488	
<u>Salix arbusculoides</u>			5/1,131			6/300	
<u>Salix alaxensis</u>			(.4)0/25		1/16		
Total Willow Density	1,042	2,949	11,717	1,603	552	2,026	7,416
Other							
<u>Rosa acicularis</u>	18/500	28/2,140	27/1,945	42/3,546	17/1,401	40/1,762	3/83
<u>Alnus crispa</u>	3/83	5/746	1/55	9/850	12/1,476	8/1,625	2/42
<u>Betula glandulosa</u>	2/42	15/2,957	27/13,386	18/3,899	11/1,854	14/3,962	
<u>Rubus idaeus</u>		1/19		2/175			
<u>Alnus incana</u>			1/292				
<u>Viburnum edule</u>				7/1,329	1/31	1/238	
Total Non-Willow Tall Shrub Density	625	5,862	15,678	9,624	4,762	7,587	125

Table 5 continued

Category	Years-Since-Burn						Fireline 1-6	
	0	1-5	6-25	Forest	26-50	51-100		100
Low Shrub Species -	(% frequency/% cover)							
<u>Ledum groenlandicum</u>	44/.12	40/4	37/4		54/5	41/5	42/3	5/.07
<u>Vaccinium uliginosum</u>	12/.12	48/3	44/5		54/7	65/5	63/8	3/.03
<u>Vaccinium vitis-idaea</u>	4/.04	45/3	50/4		76/8	92/13	96/13	2/.03
<u>Ledum decumbens</u>		15/2	5/1		7/1	15/1	22/2	
<u>Spiraea beauverdiana</u>		10/.4	6/.5		5/1	5/.2	4/.1	2/.01
<u>Vaccinium oxycoccus</u>		9/.3	1/.02		2/.04	9/.3	12/.4	
<u>Betula nana</u>		5/.2			3/.3		16/1	
<u>Empetrum nigrum</u>		3/.1	2/.04		23/1	5/.4	37/3	
<u>Chamaedaphne calyculata</u>		3/.1	(.2)0/.01				3/.2	
<u>Andromeda polifolia</u>		2/.02			(.3)0/.01			
<u>Linnaea borealis</u>		1/.01	4/.1		18/1	3/.2	6/.1	
<u>Ribes triste</u>		1/.01	(.3)0/.01		(.3)0/.003	(.4)0/.2	(.3)0/.003	2/.01
<u>Ledum species</u>		(.4)0/.01				(.4)0/.04		
<u>Salix myrtillifolia</u>			6/.1					
<u>Arctostaphylos rubra</u>			5/.4		(.5)0/.01		12/1	
<u>Potentilla fruticosa</u>			3/.2				2/.03	
<u>Dryas integrifolia</u>			1/.03				3/.1	
<u>Arctostaphylos uva-ursi</u>			1/.03		(.3)0/.1	(.4)0/.01	(.5)0/.01	
<u>Shepherdia canadensis</u>			(.2)0/.01		(.5)0/.1			
<u>Salix species</u>			(.2)0/.002				(.5)0/.02	
<u>Loiseleuria procubens</u>					(.5)0/.1			
Total Low Shrub Cover	.28	13.15	15.452		23.763	25.35	31.943	
Herb Species -	(% frequency/% cover)							
<u>Calamagrostis species</u>	72/1	55/3	69/5		44/3	65/.3	56/2	42/1
<u>Rubus chamaemorus</u>	28/.4	31/1	8/1		5/.2	24/2	21/1	7/.2
<u>Petasites frigidus</u>	5/.05	2/.05	6/.1		(.3)0/.01	6/.1	6/.1	
<u>Equisetum sylvaticum</u>	5/.05	31/2	5/1		3/.04	19/1	11/1	50/11

Table 5 continued

Category	Years-Since-Burn						Fireline 1-6
	0	1-5	6-25	Forest 26-50	51-100	>100	
Herb Species continued -							
<u>Equisetum species</u>	5/.05						
<u>Cornus canadensis</u>	5/.05	18/.4	15/1	36/3	38/2	14/.2	
<u>Geocaulon lividum</u>	2/.02	2/.03	(.5)0/.01	19/1	34/1	19/1	
<u>Graminae species</u>	2/.02		1/.05	-	1/.01	6/.2	25/6
<u>Epilobium angustifolium</u>		21/1	57/2	27/1	5/.1		63/1
<u>Carex species</u>		14/1	17/3			26/3	
<u>Trientalis europaea</u>		12/1	(.3)0/.003				
<u>Eriophorum vaginatum</u>		12/.4	(.5)0/.01		1/.01	7/.4	
<u>Equisetum scirpoides</u>		12/.2	30/2	4/.1	2/.1	18/4	
<u>Equisetum arvense</u>		8/.1	23/1	35/1	8/.1	8/.1	8/.3
<u>Juncus species</u>		5/.1	2/.02				3/.03
<u>Pyrola species</u>		2/.2	2/.1			8/.4	
<u>Corydalis sempervirens</u>		2/.1					
<u>Polygonum alaskanum</u>		2/.05	2/.03	8/.2	3/.1		2/.03
<u>Mertensia paniculata</u>		2/.03	8/.2	14/1	2/.03	12/.2	
<u>Cerastium species</u>		2/.03	2/.03				
Herb Unknown		1/.02	(.3)0/.01	2/.02	(.3)0/.03		
<u>Stellaria species</u>		1/.002	6/.1	2/.02			
<u>Polemonium acutiflorum</u>		(.4)0/.01	(.3)0/.01				
<u>Epilobium species</u>		(.1)0/.002	1/.03				
<u>Crepis nana</u>		(.1)0/.001					
<u>Equisetum pratense</u>		(.1)0/.001	2/.04				
<u>Luzula species</u>		(.1)0/.001	4/.1				2/.01
<u>Lycopodium species</u>		(.1)0/.001		1/.03			
<u>Pedicularis labradorica</u>		(.1)0/.001	(.3)0/.003	7/.3	(.3)0/.004		
<u>Pyrola secunda</u>		(.1)0/.001	2/.03	3/.05	1/.01	7/.1	
<u>Ranunculus species</u>		(.1)0/.001					
<u>Agrostis scabra</u>			21/3				47/1
<u>Achillea species</u>			6/.1		1/.01	(.5)0/.01	
<u>Astragalus species</u>			5/.1				
<u>Lupinus arcticus</u>			4/.3			6/.2	
<u>Galium boreale</u>			4/.1	(.3)0/.01	2/.02	(.5)0/.01	
<u>Moehringia lateriflora</u>			4/.05	13/.2			
<u>Pyrola asarifolia</u>			3/.1	1/.03			
<u>Aconitum delphinifolium</u>			2/.1	1/.01	(.4)0/.004		

Table 5 continued

Category	Years-Since-Burn						Fireline 1-6
	0	1-5	6-25	Forest 26-50	51-100	>100	
Herb Species continued -							
<u>Saxifraga punctata</u>			2/.04				
<u>Saussurea angustifolium</u>			2/.02			2/.03	
<u>Parnassia palustris</u>			2/.02				
<u>Rubus arcticus</u>			1/.03			(.5)0/.01	
<u>Castilleja species</u>			1/.02				
<u>Valeriana capitata</u>			1/.02			2/.02	
<u>Eriogonon species</u>			1/.01			(.5)0/.01	
<u>Iris setosa</u>			(.4)0/.004				
<u>Planthera species</u>			(.3)0/.003			2/.5	
<u>Lycopodium annotinum</u>			(.3)0/.003	6/1	12/.4	4/.1	
<u>Delphinium glaucum</u>			(.2)0/.002			(.5)0/.01	
<u>Adoxa moschatellina</u>		(.2)0/.002				(.5)0/.01	
<u>Gentiana glauca</u>			(.2)0/.002				
<u>Anemone richardsonii</u>			(.2)0/.001				
<u>Lycopodium complanatum</u>			1/.01	4/.1	1/.01	(.5)0/.02	
<u>Lycopodium clavatum</u>				2/.1	2/.03		
<u>Boschniakia rossica</u>				1/.01			
<u>Polygonum bistorta</u>				1/.01		(.3)0/.01	
<u>Solidago species</u>				(.5)0/.01			
<u>Poa species</u>				(.5)0/.01			2/.01
<u>Drosera rotundifolia</u>				(.3)0/.003		3/.01	
<u>Pinquicula villosa</u>				(.3)0/.003		(.3)0/.003	
<u>Calypso bulbosa</u>				(.3)0/.003			
<u>Goodyera repens</u>					(.4)0/.004	1/.01	
<u>Actea rubra</u>						(.5)0/.04	
<u>Chenopodium capitatum</u>							25/8
<u>Rumex species</u>							2/.01
Total Herb Cover	1.64	15.731	20.913	12.469	7.372	14.653	28.59

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Table 5 continued

Category	Years-Since-Burn						Fireline	
	0	1-5	6-25	Forest	26-50	51-100		>100
Moss Species -		(% frequency/% cover)						
<u>Polytrichum</u> species	10/.1	68/7	66/11		48/2	52/3	38/3	97/21
Moss other	2/.2	4/.1	10/1		12/.2	10/.4	16/2	32/16
<u>Ceratodon purpureus</u>		63/10	67/17		1/.01	1/.03	4/.1	63/9
<u>Sphagnum</u> species		11/2	4/1		5/1	21/7	19/10	15/.2
<u>Aulacomnium palustre</u>		11/.3	33/4		2/.05	16/2	19/2	3/.05
<u>Marchantia polymorpha</u>		7/.4	7/1					
<u>Pleurozium schreberi</u>		5/.3	15/1		69/29	81/32	50/18	20/.2
<u>Hylocomium splendens</u>		2/.04	6/.3		22/5	59/13	59/35	2/.01
<u>Ptilium crista-castrensis</u>		1/.1	1/.02		(.3)0/.003	9/.6	5/.4	
<u>Dicranum</u> species		1/.01	4/.1		22/1	33/1	28/2	2/.05
Leafy Liverwort		(.3)0/.03	5/.3		(.3)0/.003	3/.03	17/2	3/.03
<u>Campyllum</u> species		(.2)0/.002						
<u>Aulacomnium turgidum</u>			6/2		1/.1	2/.04	2/.1	5/.05
<u>Drepanocladus uncinatus</u>			1/.01		8/.2	19/1	9/.2	
<u>Rhytidiadelphus</u> species			(.2)0/.01					
<u>Mnium</u> species			(.2)0/.002				2/.1	5/.1
<u>Brachythecium salebrosum</u>							2/.1	
<u>Hypnum</u> species							(.4)0/.03	
Total Moss Cover	.3	20.27	42.74		38.566	60.10	75.00	46.69
Lichen and Mushroom Species -		(% frequency/% cover)						
Mushroom	1/.01	9/.1	11/.1		4/.1	32/.4	28/.3	23/.2
<u>Cladina rangiferina</u>	1/.01	2/.1	3/.1		35/4	23/1	28/2	
<u>Cladina arbuscula</u>		1/.01	2/.2			28/1	25/2	
<u>Cladonia amaurocraea</u>		1/.02	1/.03			5/.1	16/1	
<u>Cladonia gracilis</u>		(.1)0/.001	3/.05		15/.3	4/.05	8/.2	
<u>Cladonia alpestris</u>			(.4)0/.01		2/.02			
<u>Cladonia-Cladina</u> species		2/.1	8/.2		36/1	33/.3	38/2	10/.1
Total Cladina-Cladonia Cover	.01	.23	.59		5.32	2.45	7.2	.1

Table 5 continued

Category	Years-Since-Burn						Fireline 1-6
	0	1-5	6-25	Forest 26-50	51-100	>100	
Lichen and Mushroom Species continued -							
<u>Peltigera canina</u>		1/.01	29/1		22/1	38/2	
<u>Peltigera aphthosa</u>		(.2)0/.01	13/1	7/.4	30/1	25/1	
<u>Peltigera species</u>	1/.01	2/.02	7/1	24/3	(.4)0/.01	8/.3	
Total <u>Peltigera</u> Cover	.01	.04	3.0	3.4	2.01	3.30	0
<u>Nephroma arcticum</u>		3/.3	.3/.01	15/1	8/1	16/1	
<u>Cetraria islandica</u>		(.3)0/.01	2/.05	2/.02	20/1	22/.5	
<u>Cetraria cucullata</u>		(.3)0/.003	3/.04	7/.1		22/1	
<u>Cetraria richardsonii</u>						8/.3	
<u>Stereocaulon species</u>				5/.1	1/.1	6/.2	
<u>Cetraria pinastri</u>		2/.02	4/.04	46/.5	70/1	36/.5	
<u>Parmelia species</u>		1/.01	3/.03	45/6	77/1	56/1	
<u>Alectoria species</u>				8/.1	23/.2	22/.3	
<u>Usnea species</u>				4/.04	18/.2	22/.2	
<u>Foliose</u>		1/.05	(.3)0/.01	6/1	2/.04	9/.4	
<u>Crustose</u>			(.2)0/.002				
<u>Fruticose</u>				14/2		10/.4	
Total Lichen Cover	.03	.76	3.86	19.68	9.40	19.60	.1
Litter -		(% frequency/% cover)					
Leaf, Twig Litter	100/8	98/38	96/58	98/49	100/34	100/21	85/5
Deadwood	100/2	96/7	75/5	70/6	80/5	77/6	93/2
Charred Litter	100/97	80/53	49/15	0	(.4)0/.01	2/1	28/4
Bare Soil (% F/% C)	0	22/1	22/2	5/.2	2/.1	5/.3	98/52
Depth to Permafrost	52	>120	85; >120	62; >120	57; >110	56; >120	Rocky;136
Depth of Organic Layer	0-12	8	11	15	15	29	0

FOOTNOTES -

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ash and charred surfaces (See Fig. 23). Some mineral soil is exposed, but usually the organic layer remains but generally reduced in thickness by the fire. Thickness will vary from 0-12 cm (0-4 in) averaging approximately 3 cm (1.2 in). Also during this stage black spruce seed is being shed by cones which are still on the trees and some opened by the heat of the fire.



Figure 23.--Newly burnt stage (0 years) on climax black spruce sites in interior Alaska. This 1-month post-burn stand has sprouts of two tall shrub species, three low shrub species, five herb species, two moss species, two lichen species, and some mushrooms, for a tall shrub density of 900 stems/ha and a total cover for the rest of 3.55%.



Figure 22. -- Newly burnt area (0 years) on clear
black spruce stand in interior Alaska. This 7-month
post-burn stand has sprouts of two tall shrub species,
three low shrub species, five herb species, two moss
species, two lichen species, and some mushrooms. For
a tall shrub density of 400 stems/m² and a total cover
for the rest of 3.5%,

ash and charred surfaces (See Fig. 23). Some mineral soil is exposed, but usually the organic layer remains but generally reduced in thickness by the fire. Thickness will vary from 0-12 cm (0-4 in) averaging approximately 3 cm (1.2 in). Also during this stage black spruce seed is being shed by cones which are still on the trees and were opened by the heat of the fire.

2) Seedling-Sucker Stage (1-5 post-burn years): In these young stands the vegetation is becoming more established (see Fig. 24). Although some tree seedlings occur, suckers from underground plant parts comprise most of the vegetation. It is interesting to note that Corydalis semervirens (L.) Pers. (pale corydalis) is the only species not present in the preburned stand to produce seedlings. An average of 21 species will occur at this time.

These heavily burned stands are open. Blackened, standing, dead trees are numerous, but live trees are few. Aspen sapling-suckers will average 38/ha (Table 5). Sapling sized birch are rare. They are less likely to produce suckers since most of their suckers are stem suckers and fire is likely to scorch the birch trunks. A few relic black spruce saplings (4/ha) may occur. Black spruce seedlings are common and numerous; densities around 5,000/ha can be expected. Of the dense young aspen reproduction, (9,000/ha), most are root suckers so they exist where unburned aspen roots exist. About 1,000 birch seedlings/ha occur.

Shoots of the willows, Scouler willow, diamondleaf willow, grayleaf willow, and Bebb willow, are numerous; around 3,000 stems/ha occur. Scouler willow seems to be the most dense with 2,000 stems/ha. See Table 5 for specific values. Resin birch, rose, green alder and red raspberry are

ash and charcoal surfaces (See Fig. 23). Some mineral soil is exposed, but usually the organic layer remains but generally reduced in thickness by the fire. Thickness will vary from 0-15 cm (0-4 in) averaging approximately 3 cm (1.2 in). Also during this stage black spruce seed is being sown by cones which are still on the trees and were opened by the heat of the fire.

2) Seedling-Sucker Stage (1-2 post-burn years): In these young stands

the vegetation is becoming more established (see Fig. 24). Although some tree seedlings occur, suckers from underground plant parts comprise most of the vegetation. It is interesting to note that *Larix laricina* (L.) Pers. (pale conifers) is the only species not present in the presumed stand to produce seedlings. An average of 21 species will occur at this time.

These heavily burned stands are open. Blackened standing dead trees are numerous, but live trees are few. Aspen sapling-suckers will average 30/ha (Table 5). Sapling sized birch are rare. They are less likely to produce suckers since most of their suckers are stem suckers and fire is likely to scar the birch trunks. A few tall black spruce saplings (4/ha) may occur. Black spruce seedlings are common and numerous; densities around 5,000/ha can be expected. Of the dense young aspen reproduction (2,000/ha), most are root suckers so they exist where unburned aspen roots exist. About 1,000 birch seedlings/ha occur.

Shoots of the willows, Scotch willow, diamondleaf willow, gray willow, and Red willow, are numerous; around 3,000 stems/ha occur. Scotch willow seems to be the most dense with 2,000 stems/ha. See Table 5 for specific values. Rusty birch, rose, green alder and red raspberry are

A



B



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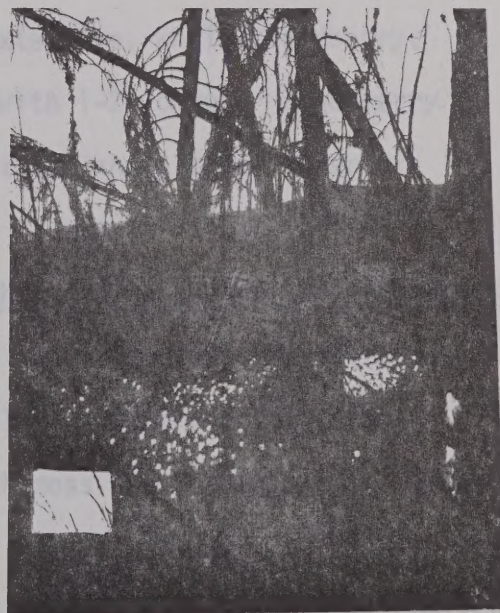


Figure 24.--Seedling-sucker stage (1-5 years) on climax black spruce sites in interior Alaska. A: a 2-year-old post-burn stand (#164) with over 130,000 aspen suckers/ha. B: an 8-year-old stand (#188) with over 5,000 birch and 1,000 black spruce seedlings/ha. C: a 3-year-old stand (#190) with almost 39,000 black spruce seedlings/ha. D: a 4-year-old stand (#108) with 1,000 black spruce and 250 birch seedlings/ha.



Figure 2A. --Seedling-sucker stage (1-5 years) on clear-cut spruce sites in Interior Alaska. A: a 5-year-old post-burn stand (1/100) with over 1,000 black spruce seedlings/m² and 500 birch seedlings/m². B: an 8-year-old stand (1/100) with over 1,000 black spruce seedlings/m² and 500 birch seedlings/m². C: a 2-year-old stand (1/100) with almost 30,000 black spruce seedlings/m². D: a 8-year-old stand (1/100) with 1,000 black spruce and 500 birch seedlings/m².

also present. Resin birch and rose each have 2,000-3,000 stems/ha. The willows, green alder, and raspberry, all of which tend to grow in clumps, have frequencies of 1-5%. Resin birch has a frequency of 15% and rose a frequency of 30%. These two species have a more general growth pattern, but may still be restricted to patches or clumps.

The low shrubs, Labrador-tea, bog blueberry, and mountain-cranberry, are common with frequencies of 40-50% and with cover values of 3-4% each. Together their cover totals 10%, which accounts for almost 2/3 of the total low shrub cover of 13%. The bog blueberry and mountain-cranberry bushes frequently produce large berries during this period. Narrow-leaf Labrador-tea and beauvered spirea are also present with frequencies around 10-15% and cover values of 2 and .4%, respectively (Table 5).

The herb layer has a total cover of 16%. Bluejoint, with a frequency around 50% and a cover of 8%, is the most extensive, while cloudberry, and woodland horsetail are both common but with 1-2% cover. Bunchberry and fireweed occur with a frequency of about 15% and a total cover of 1.5%.

The total moss cover is 20%. Polytrichum spp. and Ceratodon purpureus are two extensive and abundant moss species which occur with frequencies of at least 60% and have cover values of 7-10%. Lichens occur with a total cover of .8%. Specific values of both moss and lichen species are included in Table 5.

Litter is extensive, occurring on more than 80% of the plots. Charred litter has a cover value of 50%, deadfall litter covers 40%, and dead wood averages 7%. Small patches of exposed soil occur with a frequency of 20% and a cover of 1%. The organic layer thickness averages 8 cm (3.2 in). The permafrost level has receded; the active layer now has an average

also present. Red-barked birch and rose-hips have 2,000-3,000 stems/ha. The willows, green alders, and raspberries, all of which tend to grow in clumps, have frequencies of 1-5%. Red-barked birch has a frequency of 1% and rose-hips a frequency of 10%. These two species have a more general growth pattern, but may still be restricted to patches or clumps.

The low shrubs, Labrador-tea, bog blueberry, and mountain-cranberry, are common with frequencies of 40-50% and with cover values of 1-5% each. Together their cover totals 10%, which accounts for almost 5% of the total low shrub cover of 13%. The bog blueberry and mountain-cranberry bushes frequently produce large berries during this period. Labrador-tea and bearberry are also present with frequencies around 10-15% and cover values of 5 and 4%, respectively (Table 2).

The herb layer has a total cover of 16%. Bluejoint, with a frequency around 50% and a cover of 4%, is the most extensive, while cloudberry and woodland horsetail are both common but with 1-5% cover. Luncheon and timothy occur with a frequency of about 15% and a total cover of 1.5%.

The total moss cover is 50%. *Hylocomium* spp. and *Laricina* spp. are two extensive and abundant moss species which occur with frequencies of at least 80% and have cover values of 1-10%. Lichens occur with a total cover of 16%. Specific values of both moss and lichen species are included in Table 2.

Litter is extensive, occurring on more than 80% of the plots. Charred litter has a cover value of 50%, deadfall litter covers 40%, and dead wood averages 3%. Small patches of exposed soil occur with a frequency of 50% and a cover of 1%. The organic layer thickness averages 8 cm (3.2 in). The permafrost level has receded; the active layer now has an average

minimum depth of 1.2 m (3.9 ft).

3) Willow; Shrub Stage (6-25 post-burn years): (See Fig. 25) This slightly older stage has a flora averaging 36 species per stand.

Some small trees are now present. Black spruce are the most frequent, whereas aspen is the most dense. Their frequency values are 17% (black spruce) and 6% (aspen), while their densities are 4/ha and around 40/ha, respectively. Breast height diameters of black spruce trees will range from 3.6-7.6 cm (1.4-3.0 in). In 20-year-old stands, aspen dbh will average 5.0 cm (2.0 in). Larch, birch and even white spruce may occur, but are rare. Birch, black spruce and aspen saplings will total about 60/ha; birch is the most dense with around 50 stems/ha. Seedlings and suckers have a total density of 11,000/ha. Listed in order of decreasing frequency, tree species are black spruce (31%), aspen (15%), birch (15%), balsam poplar (12%), white spruce (10%), and larch (2%). All but the last two have seedling densities of more than 1,000/ha; while the density of black spruce is 4,500/ha. See Table 5 for exact values.

Willows and other tall shrubs are usually well-developed during this stage. Bebb willow, the most frequent and dense willow, as well as grayleaf willow, diamondleaf willow, littletree willow, Scouler willow, and fettleaf willow occur. Most have densities greater than 1,000 stems/ha. Of the non-willow tall shrubs, resin birch and rose are most important. They both occur with frequency values near 30%. Resin birch has a density of about 13,000 stems/ha, while rose has 2,000 stems/ha (Table 5).

The low shrub layer has a total cover of 15%. Labrador-tea, bog blueberry, and mountain-cranberry are the most important species with frequency and cover values of 37-50% and 4-5%, respectively, which account

minimum depth of 1.5 m (5 ft).

1) Willow: Shrub stage (5-25 years): (See Fig. 2) This

stage has a flora averaging 25 species per stand.

Some small trees are now present. Black spruce are the most frequent.

whereas aspen is the most dense. Their frequency values are 1% (black

spruce) and 6% (aspen). White spruce densities are 4/ha and around 4/ha.

respectively. Branch height diameter of black spruce trees will range

from 3.0-7.6 cm (1.2-3.0 in). In 50-year-old stands, aspen dbh will average

5.0 cm (2.0 in). Larch, birch and even white spruce may occur, but are

rare. Birch, black spruce and aspen saplings will total about 60/ha.

Birch is the most dense with around 50 stems/ha. Seedlings and suckers

have a total density of 17,000/ha. Listed in order of decreasing frequency,

tree species are black spruce (37%), aspen (15%), birch (12%), balsam

poplar (12%), white spruce (10%), and larch (5%). All but the last two

have seedling densities of more than 1,000/ha; white the density of black

spruce is 4,500/ha. See Table 2 for exact values.

Willows and other tall shrubs are usually well-developed during this

stage. Bobb Willow, the most frequent and dense willow, as well as grayish

willow, diamondleaf willow, feathered willow, scouter willow, and fetid

willow occur. Most have densities greater than 1,000 stems/ha. Of the

non-willow tall shrubs, rose birch and rose are most important. They

both occur when frequency values near 30%. Rose birch has a density

of about 17,000 stems/ha, while rose has 5,000 stems/ha (Table 2).

The low shrub layer has a total cover of 15%. Labrador-tea, bog

blueberry, and mountain-cranberry are the most important species with

frequency and cover values of 37-50% and 4-5%, respectively, which account

for 13% of the total low shrub cover. Narrow-Leaf Labrador-tea and beauvered spirea are the next most important shrubs (Table 5).

The herb layer is well developed with a total cover of about 20%. Bluejoint and fireweed are the most common species, each occurring with frequencies around 60% and cover values of 5% and 2%. Dwarf scouring-rush, Equisetum arvense, Carex spp., Agrostis scabra Willd. (tickle grass), and bunchberry are next most common but with smaller frequency (20-30%) and cover values (1-3%). Cloudberry and woodland horsetail are also important (6-8% frequency and 1% cover). See Table 5 for cover and frequency values.

Ceratodon purpureus and Polytrichum spp. are important mosses, occurring with 65% frequencies and 10-20% cover. They, along with Aulacomnium palustre, have a total cover of about 30% and account for almost 3/4 of the total moss cover. Marchantia polymorpha, which is never extensive but is unique to the young successional stages, is present with 1% cover. The Peltigera spp. lichens have a group total cover of 3% and P. canina, which is the most common, has a frequency of 30%. Cladonia spp.-Cladina spp. lichens, as a group, have 1% cover. Other lichen species occur but with very little cover (Table 5).

Litter is extensive. Charred litter has a cover value of 15%, deadfall litter of 60%, and dead wood of 5%. Much of the charred material has washed into the duff or blown away. The amount of exposed soil has increased slightly--it is now 2%. The average thickness of the organic layer is 11 cm (4.3 in). The active layer is 85 cm (33.5 in) thick.

4) Dense Hardwood; Small Diameter Black Spruce (26-50 post-burn years):

As more trees mature the stands take on an increasingly closed appearance. With this closure of the canopy the numbers of willows and tall shrubs decrease, some species disappear, and other species appear. The stand has an average flora of 34 species. This total of 34 species is, on the average, composed of 2 tree, 2 sapling tree, 2 seedling tree, 1 willow, 2 non-willow tall shrub, 4 low shrub, 8 herb, 5 moss, and 8 lichen species.

Trees, saplings and seedlings, especially black spruce, are prevalent. The black spruce average at least 1,000 trees, 800 saplings, and 2,500 seedlings/ha; while all hardwoods average 39 trees, 56 saplings, and 2,500 seedlings/ha. The hardwoods, especially the birch, attain their maximum tree densities during this 25 year period (Table 5). Black spruce tree diameters will range between 4.9 and 6.6 cm (1.9-2.6 in) dbh; while birch will range between 5.1 and 8.0 cm (2.0-3.1 in), and aspen between 7.3 and 8.5 cm (2.9-3.4 in).

Willows occur with frequencies of 2-6% and total stem densities of 1,600/ha. The densities of rose and resin birch now average 3,500-4,000 stems/ha each and green alder has a density of over 800 stems/ha (See Table 5).

The low shrub layer has a total cover of 24%. Labrador-tea, bog blueberry and mountain-cranberry are the main components with frequencies ranging from 50-75% and cover from 5-8%; cranberry possesses the higher values. Narrow-leaf Labrador-tea, crowberry and twin-flower are next most common with a total cover of 3% and frequencies of 7-25% (See Table 5).

Bluejoint and bunchberry are the most common herbs, occurring with

4) Green Hardwood: Small Diameter Black Spruce (25-50 post-burn years):

As more trees mature the stands take on an increasingly closed appearance. With this closure of the canopy the heights of willow and tall shrubs decrease, some species disappear, and other species appear. The stand has an average floor of 34 species. This total of 34 species is, on the average, composed of 2 trees, 2 saplings, 2 seedling trees, 1 willow, 2 non-willow tall shrub, 4 low shrub, 8 herb, 5 moss, and 6 lichen species. Trees, saplings and seedlings, especially black spruce, are prevalent.

The black spruce average at least 1,000 trees, 800 saplings, and 2,500 seedlings; while all hardwoods average 39 trees, 58 saplings, and 2,500 seedlings. The hardwoods, especially the birch, retain their maximum tree densities during this 25 year period (Table 5). Black spruce tree diameters will range between 4.9 and 6.5 cm (1.9-2.6 in); white birch will range between 5.1 and 8.0 cm (2.0-3.1 in), and aspen between 7.3 and 8.5 cm (2.9-3.4 in).

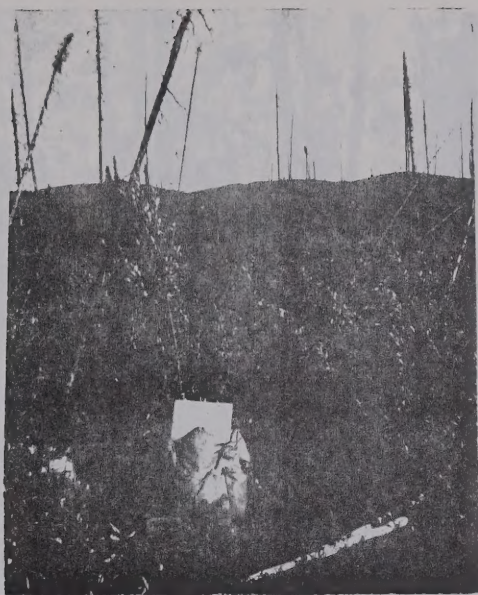
Willows occur with frequencies of 2-52 and total stem densities of 1,000/ha. The densities of rose and resin birch are average 3,500-4,000 stems/ha each and green alder has a density of over 800 stems/ha (See Table 5).

The low shrub layer has a total cover of 26%. Labrador-tea, bog blueberry and mountain-cranberry are the main components with frequencies ranging from 50-152 and cover from 5-6%; cranberry possesses the higher values. Hairy-leaved Labrador-tea, crowberry and twin-flower are next most common with a total cover of 32 and frequencies of 1-52 (See Table

5).

Bluejoint and bunchberry are the most common herbs, occurring with

A



B



C

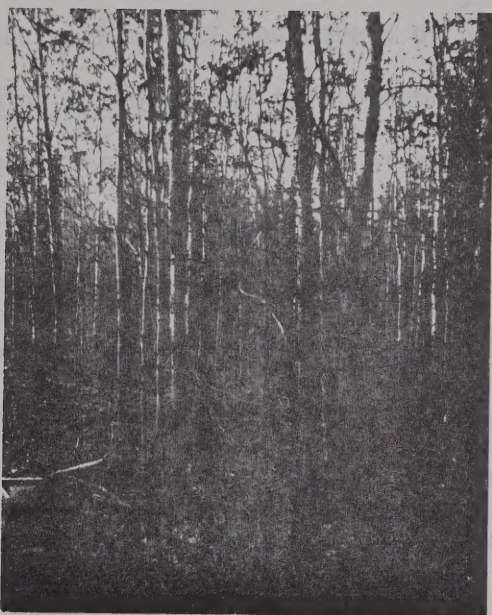


Figure 25.--Willow, shrub stage (6-25 years) on black spruce sites in interior Alaska. A: a 14-year-old post-burn stand (#119) with over 7,000 tree seedlings and 35,000 willow stems/ha. B: a 14-year-old stand (#111) with over 1,000 saplings, 105,000 seedlings, 3,000 willows, and 500 non-willow tall shrub stems/ha. C: a 10-year-old stand (#109) with 600 willow, 125 tall shrub stems/ha, and a low shrub cover of 34%.



Figure 17. Willow, shrub stage (6-25 years) on black spruce sites in Interior Alaska. A: a 14-year-old post-fire stand (1978) with mean 1,000 trees/ha and 1,000 willow stems/ha. B: a 14-year-old stand (1978) with mean 1,000 trees/ha and 1,000 willow stems/ha. C: a 10-year-old stand (1978) with 1,000 willow, 125 tall shrub stems/ha, and a low shrub cover of 2%.

A



B



C

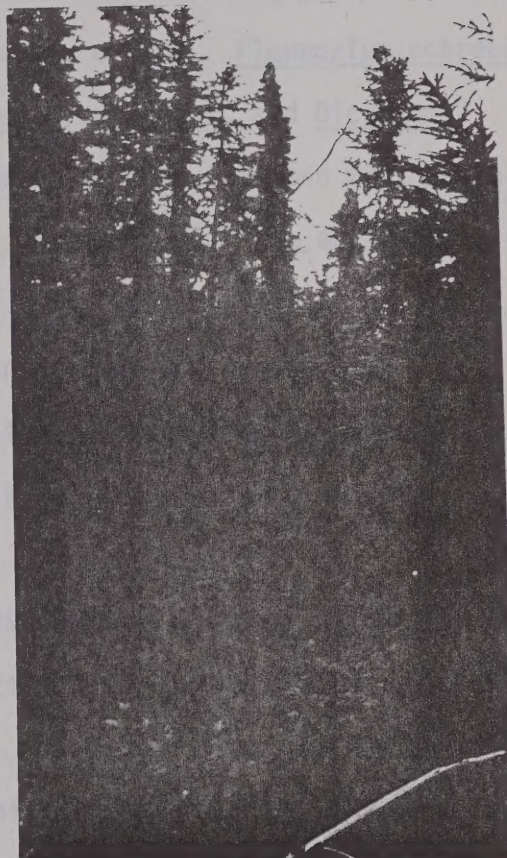


Figure 26.--Dense hardwood; small diameter spruce stage (26-50 years) on black spruce sites in interior Alaska. A: 40-year-old post-burn stand (#9) with over 2,000 trees, 12 saplings, 2,000 seedlings, 3,000 willow, and 1,000 non-willow tall shrub stems/ha. B: 38-year-old stand (#110) with over 1,000 trees, 30 saplings, 9,000 seedlings, 1,000 willow, and 700 non-willow tall shrub stems/ha. C: 43-year-old stand (#173) with over 3,000 trees, 2,000 saplings, 10,000 seedlings, 300 willow, and 9,000 non-willow tall shrub stems/ha.

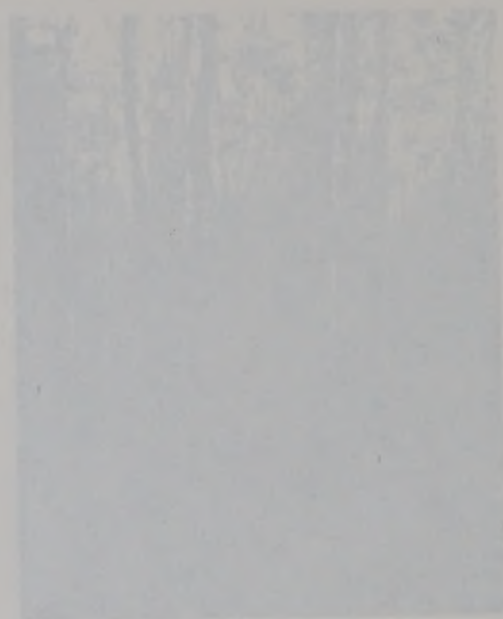


Figure 25. - Spruce forest; south of station 100 (25-25 years)
on black spruce sites in interior Alaska. At 40-year-old stand
stand (25) with over 5,000 trees, 15 saplings, 5,000 seedlings, 3,000
with, and 1,000 non-vital; tall spruce stands. At 30-year-old stand
(40) with over 1,000 trees, 10 saplings, 8,000 seedlings, 1,000 with
and 700 non-vital tall spruce stands. At 45-year-old stand (25)
with over 3,000 trees, 5,000 saplings, 10,000 seedlings, 100 with, and
2,000 non-vital tall spruce stands.

frequencies near 40% and covers of 3% each. Equisetum arvense, fireweed, Geocaulon lividum, and tall bluebell are also common, with cover values of about 1% each. The cover of all the remaining species adds to an additional 2% making the total cover of all herb species 12% (Table 5).

The extensive moss layer has a total cover of 40%. Pleurozium schreberi dominates, though Polytrichum spp., Hylocomium splendens, and Dicranum spp. are common. Their frequency values are 69%, 48%, 22%, and 22%, while their cover values are 29%, 2%, 5%, and 1%, respectively. The early succession moss, Ceratodon purpureus is now rare. The lichens have a total cover of 20%. The Cladonia spp.-Cladina spp. group of lichens have 5% cover, the Peltigera spp. lichens 3%, and the arboreal lichens growing on twig litter 7%. All species of mosses and lichens which occur are listed in Table 5.

The litter is common but less extensive than in the earlier stages. Charred litter is absent, the deadfall litter has a cover of 50%, and the dead wood has a cover of 6%.

Exposed soil is rare. The average thickness of the organic soil is 15 cm (5.9 in). The average minimum thickness of the active layer is now 62 cm (24.4 in).

5) Dense Black Spruce-Pleurozium Stage (51-100 post-burn years): Floristically this stage is similar to the last. An average of 36 species per stand occur; however, the structure of the stand has changed (Figures 8, 9, and 12). Black spruce, low shrubs and Pleurozium schreberi dominate.

Black spruce tree diameters, which range from 4.1-10.6 cm (1.6-4.2 in), now average 6.0 cm (2.4 in) dbh. The trees, saplings, and seedlings are very dense, averaging 1,500/ha, 1,000/ha, and 13,000/ha, respectively.

Many of the seedlings are layerlings. Aspen densities average 400 trees, 3 saplings, and 700 seedlings/ha, while the larger tree diameters vary from 12.3-13.4 cm (4.8-5.3 in) dbh. Birch, the next most common tree, has densities of 80 trees, 5 saplings, and 80 seedlings/ha and tree diameters ranging from 6.8-24.5 cm (2.7-9.6 in), but averaging 11 cm (4.3 in) dbh (See Table 5).

Amounts of willow continue to decline; their total density is about 500 stems/ha. Diamondleaf willow is the most prevalent. Rose, resin birch, and green alder all have densities ranging from 1,000-2,000 stems/ha, with a total density of 5,000 stems/ha.

The low shrub layer, with a total cover of 25%, continues to be extensive. Of the three important low shrubs, only mountain-cranberry has expanded since the next earlier stage. It now has a frequency of 92% and a cover of 13%. The other two, blueberry and Labrador-tea, have a frequency of 40-65% and a cover of about 5% each. Two less dominant species, narrow-leaf Labrador-tea and bog cranberry, have frequency values of 10-15% (Table 5).

Several herbs occur with high frequency, but most have little cover. Bluejoint is the most frequent with around 65% frequency, while cloudberry has the most cover with 2% cover. Woodland horsetail, bunchberry and Geocaulon lividum are common, with frequencies of 20-40% and cover values of 1% each. The entire herb layer has a total cover of 7%. See Table 5 for additional values.

The moss layer, with a total cover of 60%, is well developed. Pleurozium schreberi is both common and extensive, occurring with a frequency of about 80% and a cover of 32%. Hylocomium splendens, with 59% frequency

Many of the seedlings are leafless. Aspen densities average 400 trees/ha, and 700 seedlings/ha, while the larger tree densities vary from 10-15.4 m (4.5-5.3 in) dbh. Birch, the next most common tree, has densities of 30 trees/ha, 5 seedlings/ha, and tree diameters ranging from 5.8-14.5 cm (2.3-5.7 in), but averaging 11 cm (4.3 in) dbh (see Table 2).

Amounts of willow continue to decline; their total density is about 500 stems/ha. *Chamaenerion* willow is the most prevalent, being 100 stems/ha, and green alder all have densities ranging from 1,000-5,000 stems/ha, with a total density of 5,000 stems/ha. The low shrub layer, with a total cover of 15%, continues to be extensive. Of the three important low shrubs, only mountain-cherry has expanded since the next earlier stage. It now has a frequency of 55% and a cover of 15%. The other two, blueberry and Labrador-tea, have a frequency of 40-55% and a cover of about 5% each. Two less dominant species, narrow-leafed Labrador-tea and bog cranberry, have frequency values of 10-15% (Table 2).

Several herbs occur with high frequency, but most have little cover. Bluejoint is the most frequent with around 55% frequency, while cloudberry has the most cover with 35 cover. Woodland horsetail, bunchberry and *Ranunculus* *repens* are common, with frequencies of 20-40% and cover values of 15% each. The entire herb layer has a total cover of 15%. See Table 2 for additional values.

The moss layer, with a total cover of 50%, is well developed. *Plumose* *Selaginella* is both common and extensive, occurring with a frequency of about 50% and a cover of 35%. *Hylocomium splendens*, with 55% frequency

and 13% cover, is also important but less dominant than Pleurozium schreberi. Polytrichum spp., Sphagnum spp., Aulacomnium palustre, Dicranum spp., and Drepanocladus spp. occur with 15-50% frequency and 1-3% cover values. The lichens have a total cover of 9%. Of this total the reindeer lichens, Cladina rangiferina and C. arbuscula, have 2% cover, the Cladonia species .4%, the Peltigera species 2%, and the arboreal lichens growing on fallen twig litter, 2% cover. An additional 2% are unidentified as to lichen type and species. See Table 5 for additional information.

Litter occurs everywhere. Deadfall has a cover of about 30%, dead wood of 5%. Bare soil is rare but does occur. The organic layer averages 15 cm (5.9 in) in thickness. The minimum depth of the active layer averages 57 cm (22.4 in).

6) Mature Black Spruce/Feathermoss Stage (>100 post-burn years):

This is the final stage in the sequence of post-fire succession on black spruce sites and includes some stands which occur on black spruce sites and some which occur on black spruce dominated mixed spruce sites (see Figures 13, 15-17). The flora of this stage is the most diverse in the black spruce succession, averaging 39 species per stand.

Black spruce trees, saplings and seedlings dominate the stand. The trees have an average density of about 1,600/ha and diameters that range from 5.3-13.0 cm (2.1-5.1 in), but average 7.6 cm (3.0 in) dbh. The saplings, with around 200/ha, and seedlings, with about 7,000/ha, insure black spruce will replace black spruce. Other species, mainly white spruce and birch occur, with lower densities (Table 5) but usually with larger diameter trees; white spruce diameters range from 4-20 cm (1.6-7.9 in), but average 9.2 cm ((3.6 in) dbh; while the birch range from 8-11 cm (3.2-4.3 in)

and 13% cover, is also important but less dominant than *Pleurostium* ssp. *Pleurostium* ssp., *Yoshimizu* ssp., *Infusum* ssp., *Cladonia* ssp., and *Oreocladia* ssp. occur with 15-50% frequency and 1-25% cover values. The lichens have a basal cover of 5%. Of this total the remaining lichens, *Cladonia rangiferina* and *C. arbuscula*, have 5% cover, the *Cladonia* species 4%, the *Pleurostium* species 2%, and the remaining lichens growing on fallen twig litter, 2% cover. An additional 2% are unidentified as to lichen type and species. See Table 5 for additional information.

Litter occurs everywhere. *Decidua* has a cover of about 30%, dead wood of 25%. Bark soil is rare but does occur. The organic layer averages 15 cm (5-8 in) in thickness. The minimum depth of the active layer averages 57 cm (15-4 in).

5) Mature Black Spruce/Pine Stage (> 100 post-burn years): This is the final stage in the sequence of post-fire succession on black spruce sites and includes some stands which occur on black spruce sites and some which occur on black spruce dominated mixed spruce sites (see Figure 13, 15-17). The first of this stage is the most diverse in the black spruce succession, averaging 25 species per stand.

Black spruce trees, seedlings and seedlings dominate the stand. The trees have an average diameter of about 150mm and diameter that range from 5-250 mm (2-1-2-7 in), but average 15 cm (5-0 in) dbh. The seedlings, with around 500/m², and seedlings, with about 7,000/m², mature black spruce with mature black spruce. Other species, mainly white spruce and black spruce, with lower densities (Table 5) but usually with larger diameter trees; white spruce diameter range from 4-50 cm (1-5-1-9 in), but average 9 cm (3-5 in) dbh; while the black spruce range from 2-15 cm (1-5-4-3 in).

diameter, but average 9.8 cm (3.9 in) dbh.

Willow occurs with a total density of about 2,000 stems/ha. No one species dominates but grayleaf willow, Bebb willow, littletree willow and diamondleaf willow were identified. Resin birch is the most dense non-willow tall shrub with around 4,000 stems/ha, while rose has the highest frequency values--about 40%. Green alder is the third most important non-willow tall shrub. All together they have a total density of 7,500 stems/ha (Table 5).

The low shrub strata, with a total cover of 32%, is well developed; mountain-cranberry, bog blueberry, Labrador-tea and crowberry are common and extensive (95-40% frequency and 13-3% cover). Narrow-leaf Labrador-tea, and dwarf arctic birch are common but less extensive (15-25% frequency and 1-2% cover). See Table 5 for other, less common species.

Calamagrostis spp. (usually bluejoint), cloudberry, woodland horsetail, Geocaulon lividum, sedge, and dwarf scouring-rush are herbs with cover values of 1-3% and frequency values of 20-60%. Of these Calamagrostis spp. has the highest frequency while sedge has the most cover. The entire herb layer has a combined total cover of 15%. See Table 5 for complete listing.

The moss layer, with a total cover of 75%, is extensive, with the feathermosses, Hylocomium splendens and Pleurozium schreberi, being the most important, with frequency values between 50-60%. Hylocomium splendens, with about 35% cover, has twice the cover of Pleurozium schreberi, with 18% cover. Other important common mosses are Polytrichum spp., Sphagnum spp., Dicranum spp., leafy liverworts and Aulacomnium palustre. These occur with frequency values of 15-40% and cover values of 2-10%. Of these,

stems, but average 2.5 in (2.5 in) dbh.

Willow occurs with a total density of about 1,000 stems/ha. No one species dominates but grayish willow, black willow, *Salix glauca* and *Salix nigra* are the most common. Willow stems are identified. Willow brush is the most dense non-willow tall shrub with around 4,000 stems/ha. Willow rose has the highest frequency values—about 40%. Green alder is the third most important non-willow tall shrub. All together they have a total density of 1,500 stems/ha (Table 2).

The low shrub strata, with a total cover of 35%, is well developed; mountain-rose, dog rose, Labrador-tea and cranberry are common and extensive (95-100% frequency and 15-30% cover). Hairy-leaved Labrador-tea, and dwarf birch are common but less extensive (75-95% frequency and 1-25% cover). See Table 2 for other, less common species.

Calamagrostis spp. (usually *Calamagrostis canadensis*, woodland horsetail), *Deschampsia flexuosa*, sedge, and dwarf sedge-rush are herbs with cover values of 1-25 and frequency values of 50-100%. Of these *Calamagrostis* spp. has the highest frequency while sedge has the most cover. The entire herb layer has a combined total cover of 15%. See Table 2 for complete listing.

The moss layer, with a total cover of 75%, is extensive, with the feathermosses, *Hypnum splendens* and *Pleurozium schreberi*, being the most important, with frequency values between 50-100%. *Hypnum splendens*, with about 35% cover, has twice the cover of *Pleurozium schreberi*, with 15% cover. Other important common mosses are *Polytrichum* spp., *Sphnum* spp., *Grimmia* spp., *Leucobryum* and *Aulacomnium patens*. These occur with frequency values of 15-40% and cover values of 5-10%. Of these,

Polytrichum spp. has the highest frequency, while Sphagnum spp. has the highest cover. (See Table 5.)

The lichens have a total cover of 20%. Of this, the reindeer lichens, Cladina rangiferina and C. arbuscula, have 4% cover, the Cladonia spp. lichens 3% cover, the Peltigera spp. lichens 3% cover, the arboreal lichens which grow on fallen twig litter 2% cover, and the remaining 7% is contributed by undertermined species (Table 5).

Much of the deadfall litter is engulfed by the feathermoss layer; it has a cover of 21%. Deadwood has a cover of 6%. Occasional charred litter can be seen. The organic layer thickness now averages 29 cm (11.4 in) and the minimum depth of the active layer is 56 cm (22 in).

5. General Patterns of Change Occurring in Succession on Black Spruce Sites and Black Spruce-Dominated Mixed-Spruce Sites. -- Thus far the discussion has largely been a description of each separate successional stage. A look at figures 27 and 28 will help to synthesize the effect of time. Each graph takes one stratum and shows how the species composition changes as succession proceeds. Figures 27A-27E depict the average densities of the trees, saplings, seedlings, willows, and non- willow tall shrubs. Note the density scale varies from one graph to another. Figures 28F-28J depict the average percent cover values for low shrubs, herbs, mosses and liverworts, lichens and litter. Graph 28K shows changes in the average thickness of the organic soil layer, 28L shows the minimum depth of the active or seasonal frost layer, and 28M shows the change in floristic diversity.

Black spruce is the primary tree species in the succession on black spruce sites. It comes in immediately following fire. Since its cones

Polystichum spp. has the highest frequency, while *Equisetum* spp. has the

highest cover. (See Table 2.)

The lichens have a total cover of 50%. Of this, the vascular lichens,

Cladonia rangiferina and *C. arbuscula*, have 4% cover, the *Cladonia* spp.

lichen 3% cover, the *Polysporus* spp. lichen 3% cover, the vascular lichens

which grow on fallen twigs 17% cover, and the remaining 7% is contributed

by unidentified species (Table 2).

Much of the deadfall litter is occupied by the *Leptogium* layer;

it has a cover of 31%. Deadwood has a cover of 8%. Occasional charred

litter can be seen. The organic layer thickness was averaged 29 cm (17.4

in) and the minimum depth of the active layer is 56 cm (22 in).

5. General Pattern of Change Occurring in Succession on Black Spruce

Sites and Black Spruce-Dominated Mixed-Spruce Sites. -- Thus far the discussion

has largely been a description of each separate successional stage. A

look at figures 27 and 28 will begin to synthesize the trends of time.

Each graph takes one attribute and shows how the species composition changes

as succession proceeds. Figures 27A-28E depict the average densities

of the trees, saplings, seedlings, shrubs, and non-woody call shrubs.

Note the density scale varies from one graph to another. Figures 27A

and 28A depict the average percent cover values for low shrubs, herbs, mosses

and liverworts, lichens and moss. Figure 28B shows changes in the average

thickness of the organic soil layer, 28C shows the minimum depth of the

active or residual forest layer, and 28D shows the change in floristic

diversity.

Black spruce is the primary tree species in the succession on black

spruce sites. It comes in immediately following fire. Since the cones

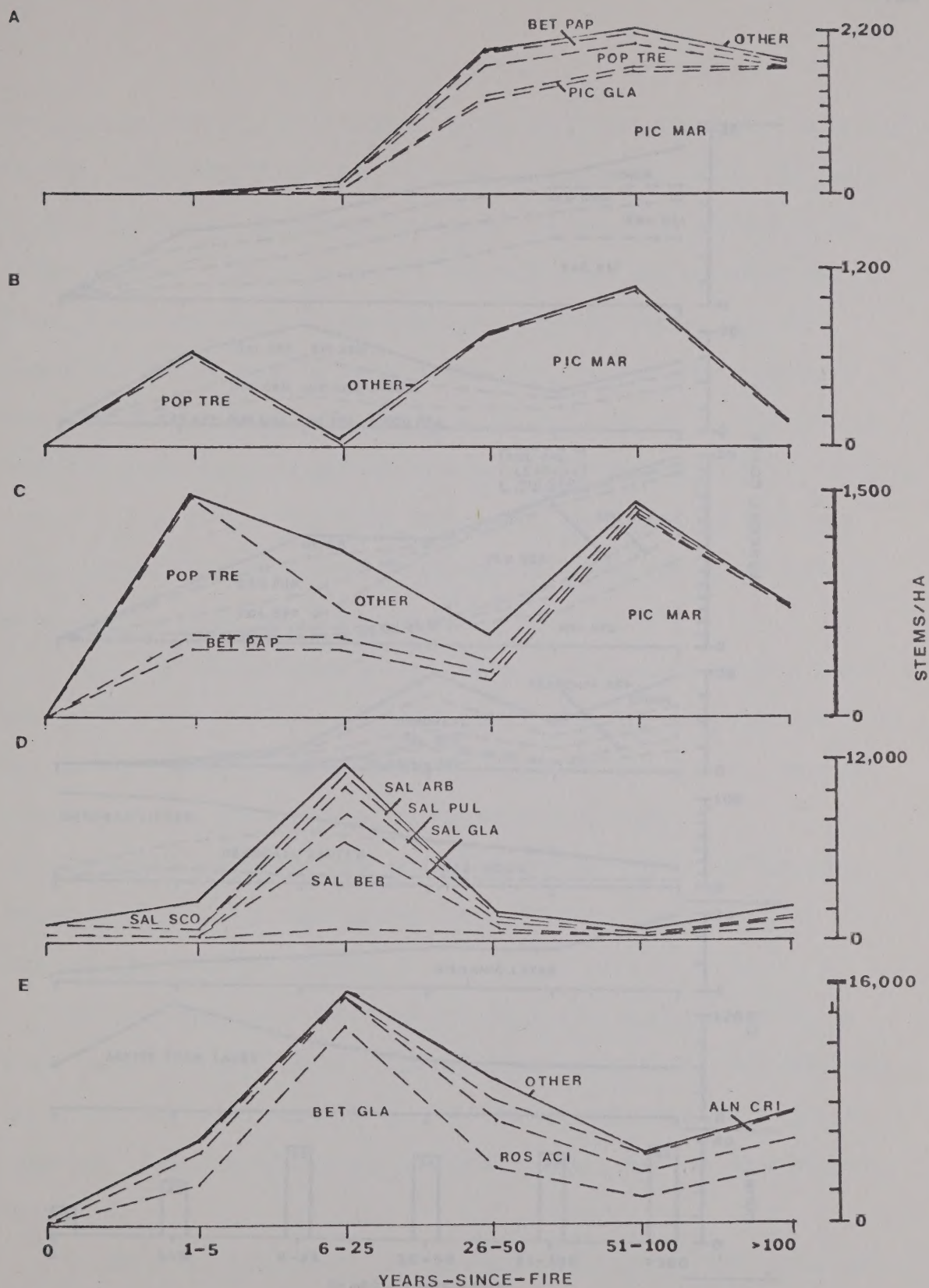


Figure 27.--Graphs showing successional trends on burned black spruce sites. A) Tree densities, B) Sapling densities, C) Seedling densities, D) Willow densities, and E) Non-willow densities. See text for more discussion.

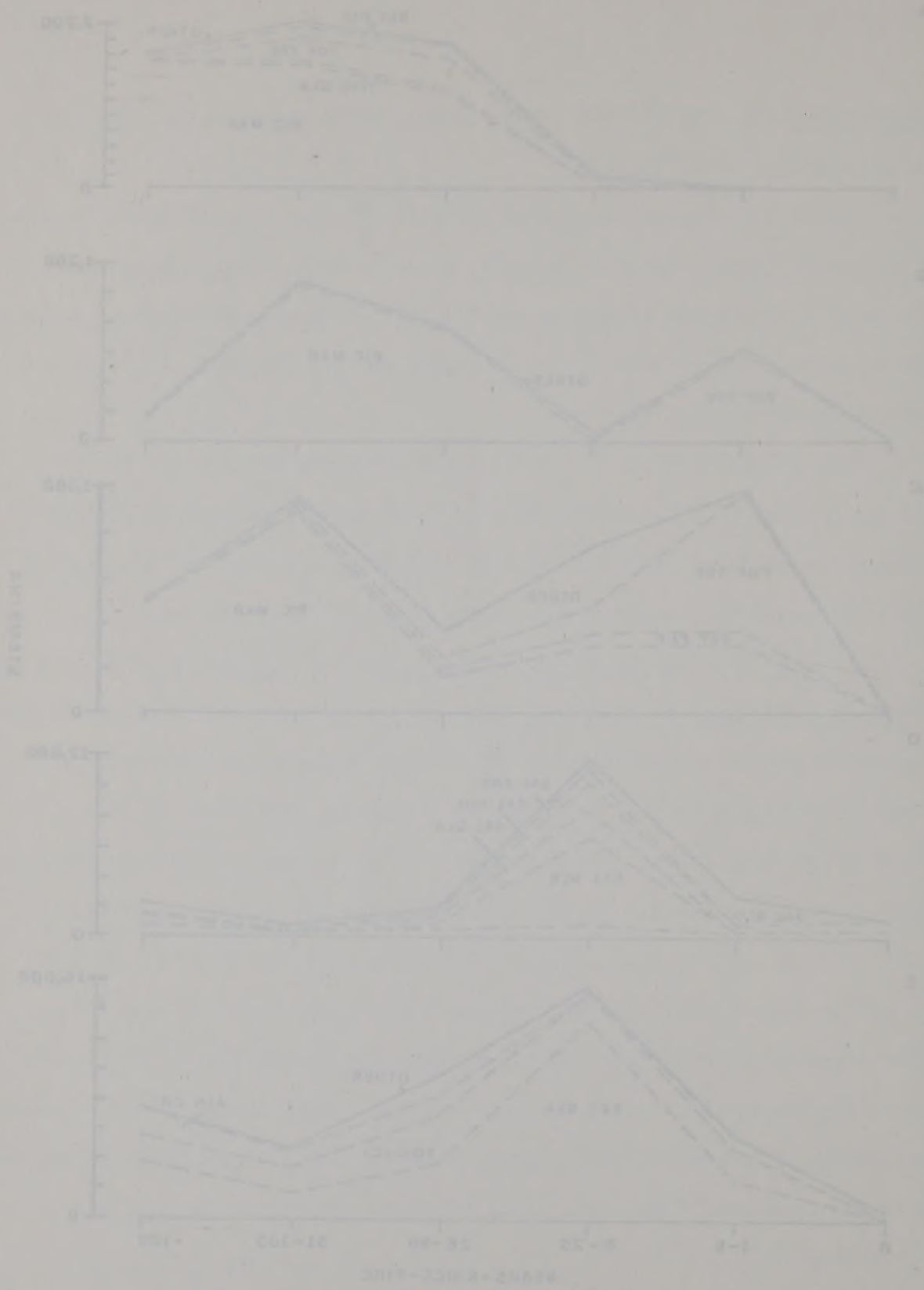


Figure 5. -- Density of various bird species (per hectare) in marsh areas. A) Red-wing, B) Green-wing, C) Yellow-bellied, D) Yellow-bellied, and E) Yellow-bellied. See text for more details.

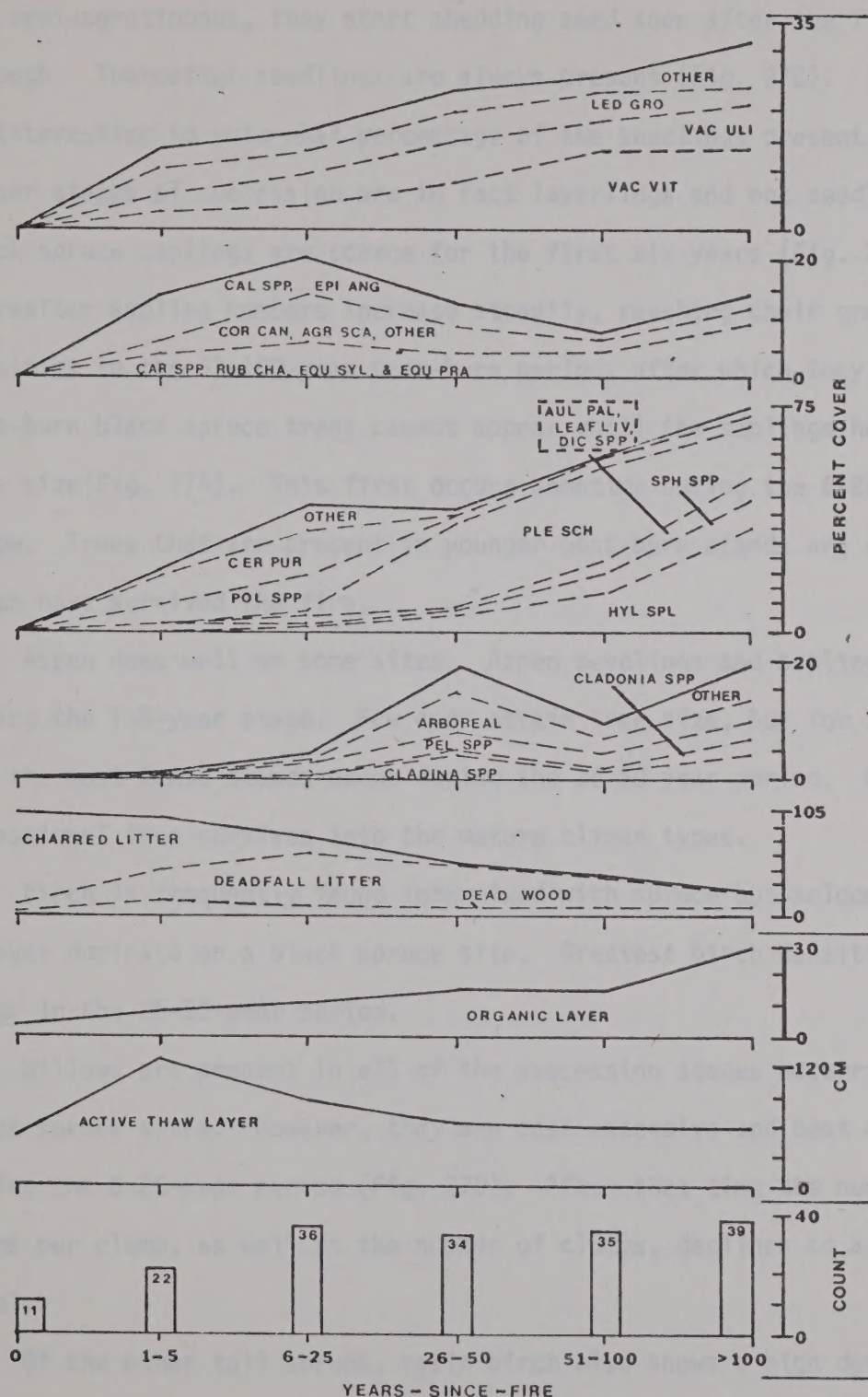


Figure 28.--Graphs showing successional trends on burned black spruce sites (continued). F) Low shrub cover, G) Herb cover, H) Moss and Liverwort cover, I) Lichen and mushroom cover, J) Litter cover, K) Thickness of the organic layer, L) Thickness of the active thaw layer, and M) Average number of plant species per stand. See text for more discussion.

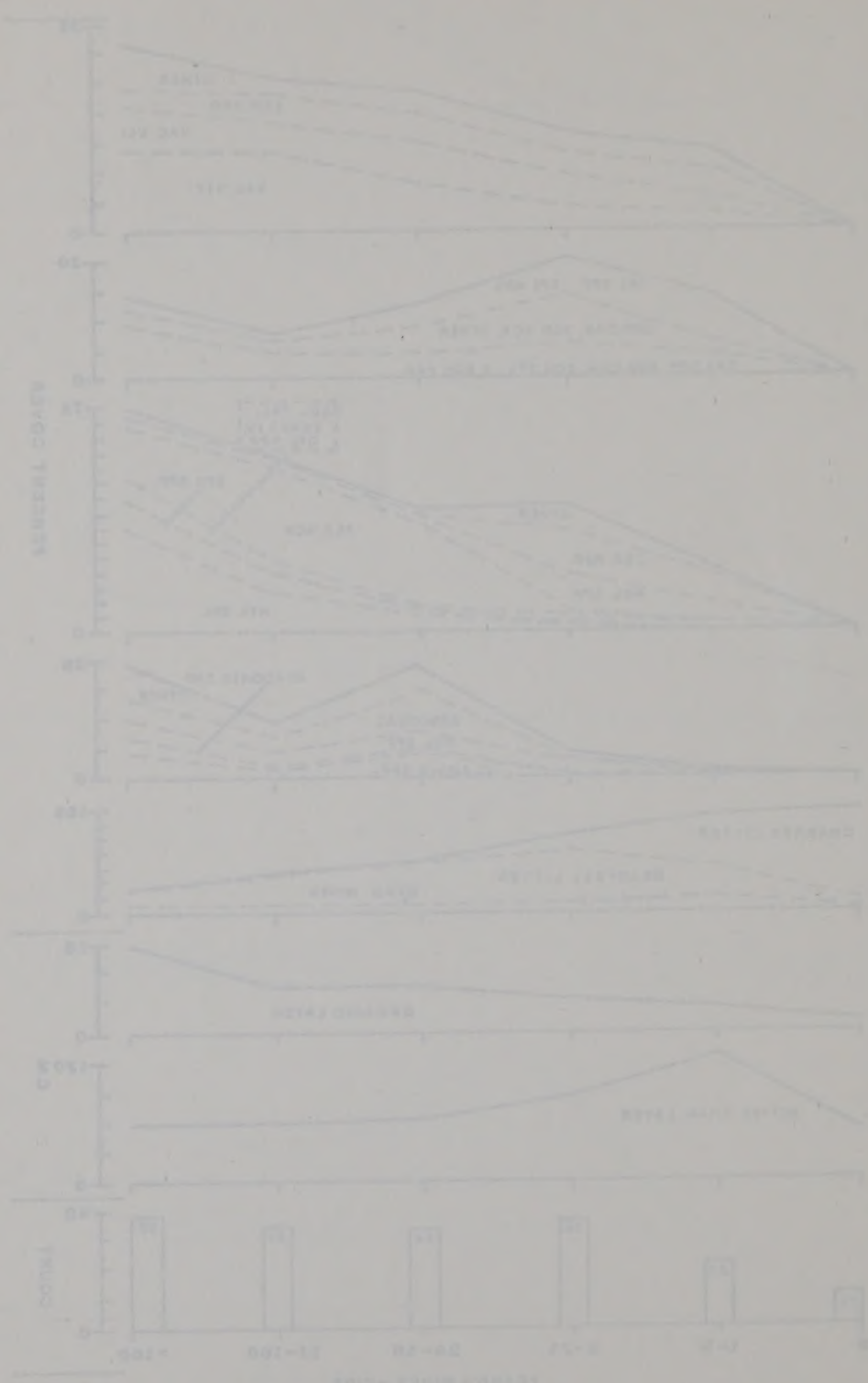


Figure 25. Sedimentation rates on various sites. The graphs show the sedimentation rate for different sites over time. The bar chart shows the sedimentation rate for different sites.

are semi-serotinous, they start shedding seed soon after the fire passes through. Thereafter seedlings are always present (Fig. 27C). It would be interesting to note what percentage of the seedlings present in the latter stages of succession are in fact layerlings and not seedlings. Black spruce saplings are scarce for the first six years (Fig. 27B). Thereafter sapling numbers increase steadily, reaching their greatest densities in the 51-100-year post-burn period, after which they decline. Post-burn black spruce trees cannot appear until the saplings have attained tree size (Fig. 27A). This first occurs sometime during the 6-25-year stage. Trees that are present in younger post-burn stands are relics which have survived the fire.

Aspen does well on some sites. Aspen seedlings and saplings flourish during the 1-5-year stage. Few ever attain tree size, but for those that do, the most dense stands occur during the 26-50 year period. Only an occasional tree survives into the mature climax types.

Birch is frequently found intermixed with spruce but seldom does it ever dominate on a black spruce site. Greatest birch densities also occur in the 26-50-year period.

Willows are present in all of the succession stages occurring on black spruce sites. However, they are most extensive and best developed during the 6-25-year period (Fig. 27D). After that time the number of stems per clump, as well as the number of clumps, declines to a minimal level.

Of the other tall shrubs, resin birch also shows a high during this 6-25-year period (Fig. 27E). Even though its density thereafter declines it is usually present in important amounts. Rose densities fluctuate

are semi-permanent, they start shedding soon after the first winter through. Thereafter seedlings are always present (Fig. 23C). It would be interesting to note what percentage of the seedlings present in the latter stages of succession are in fact juveniles and not seedlings. Black spruce seedlings are scarce for the first six years (Fig. 23B). Thereafter seedling numbers increase steadily, reaching their greatest densities in the 21-110-year post-burn period, after which they decline. Post-burn black spruce trees cannot appear until the seedlings have attained the 1-5-year stage (Fig. 23A). This first occurs sometime during the 5-25-year stage. Trees that are present in younger post-burn stands are saplings which have survived the fire.

Aspen does well on some sites. Aspen seedlings and saplings flourish during the 1-5-year stage. For even sites tree size, but for those that do, the seed stands occur during the 15-50 year period. Only an occasional tree survives into the mature climax types. Birch is frequently found intermixed with spruce but seldom does it ever dominate on a black spruce site. Greatest birch densities after occur in the 25-50-year period.

Willows are present in all of the succession stages occurring on black spruce sites. However, they are most extensive and best developed during the 5-25-year period (Fig. 23D). After that time the number of shrub per acre, as well as the number of clumps, declines to a minimal level.

Of the other tall shrubs, red-barked dogwood shows a high density 5-25-year period (Fig. 23E). Even though its density thereafter declines it is usually present in important amounts. Rose hedges fluctuate

somewhat and even decline in the later stages but the changes are not dramatic. Green alder, on the other hand, tends to increase in density with increasing post-burn stand age.

All the important low shrubs, mountain-cranberry, bog blueberry, Labrador-tea, narrow-leaf Labrador-tea, bog cranberry, dwarf arctic birch, and crowberry, first appear in small amounts and increase in cover values with the increasing post-burn time (Fig. 28F). A few, like twin-flower, occur in small amounts in the middle successional stages.

Some herbs, such as sedges, cloudberry, woodland horsetail, and E. pratense, occur in small to moderate amounts during the early stages and increase in significance in the later stages (Fig. 28G). Other species, such as bunchberry and ticklegrass, are most extensive during the 6-25-year period though they persist thereafter. Calamagrostis spp. and fireweed attain high cover values during the 1-5-year period, after which their frequency values increase but their cover values stay the same or decrease. That is, numerous clumps or patches still exist, but each is slowly declining in size.

Three trends are apparent in the mosses (Fig. 28H). Hylocomium splendens, Sphagnum spp., Aulacomnium palustre, and Dicranum spp. all return slowly after fire. However, with increasing post-burn time they all steadily increase until finally in the mature stands they are important components of the moss layer. Pleurozium schreberi is faster to return and for a long while dominates, but in the older stands this dominance wanes. Some species, like Ceratodon purpureus and Marchantia polymorpha, are important during the early stages but are rare in the older stages.

remains the same during the later stages but the changes are not dramatic. Brown alder, on the other hand, tends to increase in density with increasing post-burn time.

All the important tree species, mountain-ash, dog blueberry, Labrador-tea, narrow-leaf Labrador-tea, dog cowberry, dwarf arctic birch, and crowberry, first appear in small amounts and increase in cover values with the increasing post-burn time (Fig. 20). A few, like white-flower, occur in small amounts in the middle successional stages.

Some herbs, such as sedges, cloudberry, woodland sorrel, and E. pratensis, occur in small to moderate amounts during the early stages and increase in significance in the later stages (Fig. 20). Other species, such as bunchberry and ticklegrass, are most extensive during the 5-15-year period though they persist thereafter. *Calamagrostis* spp. and *Trisetum* attain high cover values during the 1-5-year period, after which their

frequency values increase but their cover values stay the same or decrease. That is, numerous clumps or patches still exist, but each is slowly declining in size.

Three trends are apparent in the weeds (Fig. 20). *Hyssopus* spp., *Sonchum* spp., *Achillea millefolium*, and *Bidens* spp. all return slowly a few years. However, with increasing post-burn time they all steadily increase until finally in the mature stands they are important components of the weed layer. *Phytolacca americana* is faster to return and for a long while dominant, but in the older stands this dominance wanes. Some species, like *Castilleja parviflora* and *Mercurialis perennis*, are important during the early stages but are rare in the older stages.

Lichens are slow to reappear after fire (Fig. 28I). The Peltigera species seem to be the first ground lichens to reappear. They first attain moderate amounts during the 26-50 year period. Our study showed a temporary decline in the next older stage followed by an increase in the older mature stage. More work is needed to determine the cause of the fluctuation.

Of the litter categories, dead wood occurs in about the same amount through time (Fig. 28J). Deadfall litter is present in large amounts until the moss layer, especially the feathermoss layer, develops sufficiently to engulf it, thereafter there is a decreasing trend. Charred litter is extensive immediately after fire but decreases steadily in amount. Some is still present in the 6-25 year period; thereafter it is rare.

After the burn organic soil thickness averages 3 cm (1.2 in). It develops steadily in thickness and in mature stands it averages 30 cm (11.8 in)(Fig. 28K).

Permafrost shows a different trend (Fig. 28L). Immediately after the fire the active layer, with a minimum depth of 52 cm (20.5 in), is similar to that found in mature stands. However, in the 1-5 year period the permafrost melts due to the reduction in the moss insulation, the blackened surface and the increased albedo of the ground, and the active layer deepens to more than 120 cm (3.9 ft). With time this melting trend is reversed. This happens sometime during the 6-25 year period. In the following years the permafrost slowly reforms closer to the ground surface until finally the active layer is reduced to a minimum depth of 56 cm (22 in).

With the passage of time the flora on the black spruce sites becomes more diverse, rapidly at first, and then more slowly after the willow

shrub stage. Young, newly burned stands average 10 species, the willow; shrub stage averages 36, and mature stands average 39 species.

6. Specific Succession Patterns Occurring on Black Spruce Sites and Black Spruce-Dominated Mixed-Spruce Sites. -- This discussion would not be complete without a few words on how succession in aspen-black spruce/Cornus stands, black spruce-hardwood/Calamagrostis stands, black spruce/lichen stands, black spruce/Labrador-tea/Equisetum sylvaticum stands, and black spruce/ narrow-leaf Labrador-tea/Sphagnum stands, differs from each other and from the general pattern.

In some respects the succession in all of these types is similar and in other respects it is not similar. That is, species such as black spruce, Scouler willow, Bebb willow, grayleaf willow, rose, green alder, Labrador-tea, bog blueberry, mountain-cranberry, Calamagrostis spp., Equisetum scirpoides, Polytrichum spp., Ceratodon purpureus, Pleurozium schreberi, Hylocomium splendens, and Parmelia spp. are ubiquitous. However, the frequency with which they occur and the extensiveness of their cover vary. There are, however, a few species that are restricted to one or two types.

If one thinks of black spruce sites as comprising a continuum of dry/cool to wet/cool sites, the aspen-black spruce/Cornus type, the black spruce-hardwood/Calamagrostis type, and the black spruce/lichen type would be found on dry/cool sites, the black spruce/Labrador-tea/Equisetum sylvaticum type on the moist/cool sites and the black spruce/narrow-leaf Labrador-tea/Sphagnum type on the wet/cool-cold sites. Many of the plant species show a preference to these conditions by their distribution patterns.

shrub stage. Young, newly burned stands average 70 species, the willow shrub stage average 85, and mature stands average 99 species.

6. Some of the Succession Patterns Occurring on Black Spruce

Black and Black Spruce-Dominated Mixed-Spruce Stage. -- This discussion

would not be complete without a few words on how succession in open-

black spruce stands, black spruce-hardwood (*C. canadensis*)

stands, black spruce/tichen stands, black spruce/Labrador-tichen

stands, and black spruce/narrow-leaf Labrador-tichen

stands, differ from each other and from the general pattern.

In some respects the succession in all of these types is similar

and in other respects it is not similar. That is, species such

as black spruce, scouter willow, larch willow, gray-leaf willow, rose,

green alder, Labrador-tichen, bog blueberry, mountain-cranberry, *C. canadensis*

sp., *L. canadensis*, *P. canadensis*, *P. canadensis* sp., *C. canadensis*

P. canadensis, *H. canadensis*, and *P. canadensis* sp. are

ubiquitous. However, the frequency with which they occur and the

extensiveness of their cover vary. There are, however, a few species

that are restricted to one or two types.

If one thinks of black spruce sites as comprising a continuum

of dryness to wetness, the open-black spruce/tichen type,

the black spruce-hardwood (*C. canadensis*) type, and the black spruce/tichen

type would be found on dryness sites, the black spruce/Labrador-

tichen stands type on the moist sites and the black

spruce/narrow-leaf Labrador-tichen type on the wettest sites.

Many of the plant species show a preference for these conditions

by their distribution patterns.

1) Succession in the Aspen-Black Spruce/Cornus Stand Type:

See Fig. 24A, 25A, 26A, and 8. Aspen seeds are windblown; consequently, aspen seedlings may occur almost anywhere. However, as aspen persists longest on warm sites, this type is most often found on south-facing slopes but it may also occur in isolated clones on east or west-facing slopes, or even on upland valley sites. Aspen is the only species to occur in aspen stands with constantly high frequencies throughout the succession process. During the first 25 post-fire years the following species are common, that is, they have frequencies of 50-100%: aspen seedlings, birch seedlings, Bebb willow, fireweed, Polytrichum spp. and Ceratodon purpureus. For the next 25-year period (26-51-post-burn)years, the following become common: aspen trees, Equisetum arvense, mountain-cranberry and Pleurozium schreberi. The oldest aspen-black spruce stands occur in the 51-100-year age-group and the following species are important: aspen trees, black spruce trees, saplings and seedlings, highbush cranberry, mountain-cranberry, Calamagrostis spp. (mostly bluejoint), bunchberry, and Parmelia spp.

Highbush cranberry, of all these species, comes the closest to being unique to warm sites. It occurs on the warmest black spruce sites but is better developed on the aspen-white spruce sites. Willows, especially Bebb willow, flourish, making these aspen sites the most productive black spruce sites in terms of willow production. Gound litter is extensive, but the organic layer is shallow, 3-11 cm (1.2-4.3 in) even in the older stands. The active layer or seasonal frost layer is thicker than 100 cm (39.4 in) in all

(1) Succession in the Aspen-Birch Spruce-Cornus Stand Type

See Fig. 5A, 5B, 5C, and 5. Aspen seeds are widespread, consequently, aspen seedlings may occur almost anywhere. However, as aspen germinates fastest on warm sites, this type is most often found on south-facing slopes but it may also occur in shaded places on east or west-facing slopes, or even on upland valley sites. Aspen is the only species to occur in aspen stands with constantly high frequencies throughout the succession process. During the first 25 post-fire years the following species are common, that is, they have frequencies of 50-100%: aspen seedlings, birch seedlings, black willow, flowered dogwood, and *Cornus* spp. For the next 25-year period (25-50 post-fire years), the following become common: aspen trees, *Pinus strobus*, *Pinus canadensis*, and *Pinus resinosa*. The oldest aspen-birch spruce stands occur in the 51-100-year age-group and the following species are important: aspen trees, black spruce, tamar, seedlings and seedlings, alder, mountain-cornus, *Salix* spp. (mostly *Salix*), *Pinus* spp., and *Pinus*.

Highland cornus, of all these species, shows the clearest tendency to occur on warm sites. It occurs on the warmest black spruce sites but is better developed on the aspen-white spruce sites. Willow, especially black willow, flourishes, being these aspen sites the most productive black spruce sites in terms of willow production. Ground litter is extensive, but the organic layer is shallow, 2-15 cm (1.5-4.5 in) over the black spruce. The active layer, or seasonal frost layer is thicker than 100 cm (32.4 in) in all

but the oldest stands. Where the moss and black spruce occur it averages 58 cm (22.8 in) in minimum thickness. As the stand develops the flora increases from 16 species per stand in the earliest post-burn period to 40 species per stand during the 26-50 year period, and then declines to 36 species per stand in the mature period.

Soon after burning aspen shoots appear from the unburned root system. Within 2-3 years the stand becomes a green mass in which travel and sight is difficult. This thicket condition remains until the lowest aspen branches become 1-2 m (3-6 ft) above the forest floor (after 6-10 years).

2) Succession in the Black Spruce-Aspen-Birch/Calamagrostis

Stand Type: See Figs. 24B, 25B, 26B, and 9. This type is primarily black spruce with a sprinkling of birch and aspen in it. Both birch and aspen seed are wind blown. This type can occur almost anywhere black spruce occurs. However, it appears most extensively on cool, well-drained sites. Black spruce, birch, mountain-cranberry, and Calamagrostis spp. occur with high frequencies throughout the succession. Rose, dwarf scouring-rush, Ceratodon purpureus, and Aulacomnium palustre are common with 50-100% frequencies during the first five year post-fire period; and fireweed the first twenty-five post-fire years. Labrador-tea, bog blueberry, Pleurozium schreberi, and Polytrichum spp., with 50-100% frequencies, are common during the next 25 years, or during the 26-50-year post-fire period. Narrow-leaf Labrador-tea, Pleurozium schreberi, Hylocomium splendens, Parmelia spp. and Cetraria pinastre, with 50-100% frequencies, are common in the still older stands (over 51 years).

but the oldest stands. When the moss and black spruce occur in
averages 55 cm (21.6 in) in minimum thickness. As the stand develops
the floor increases from 15 species per stand in the earliest post-
burn period to 40 species per stand during the 50-80 year period,
and then declines to 30 species per stand in the mature period.
Soon after burning aspen stands appear from the unburned forest
system. Within 2-3 years the stand becomes a green mass in which
crystal and slight is difficult. This thicket condition remains until
the lowest aspen branches become 1-2 m (3-6 ft) above the forest
floor (after 5-10 years).

5) Succession in the Black Spruce-Aspen-Birch-Cottonwood

Stand Type: See Figs. 248, 255, 256, and 2. This type is primarily
black spruce with a sprinkling of birch and aspen in it. Both birch
and aspen seed are wind blown. This type can occur almost anywhere
black spruce occurs. However, it occurs most extensively on cool,
well-drained sites. Black spruce, birch, mountain-spruce, and
Calamagrostis spp. occur with high frequencies throughout the succession.
Roses, dwarf-scurvy-grass, *Carex* spp., and *Polygonum*
sp. are common with 50-100% frequencies during the first five
year post-fire period, and toward the first twenty-five post-fire
years. Labrador-tea, bog blueberry, *Polygonum* spp., and
Polygonum spp. with 50-100% frequencies, are common during the
next 25 years, or during the 25-50 year post-fire period. Herring-
bone-leaved, *Polygonum* spp., *Hylocomium splendens*, *Polytrichum*
spp. and *Carex* spp. with 50-100% frequencies, are common
in the still older stands (over 50 years).

Even though this type produces fewer willows than the aspen-black spruce stands, it is still an important type for willow production. Diamondleaf willow, grayleaf willow, and littletree willow all attain their greatest densities in this black spruce-hardwood type. Scouler willow, Bebb willow, and feltleaf willow also occur.

A few additional species are less common but still important and should be mentioned. Equisetum arvense has a cover of 2-3% in stands with a post-burn age of 6-50 years. This species appears to prefer the warmest sites, since it was also important in the aspen stand type. Geocaulon lividum, which has the same cover, seems to prefer the cooler, well-drained sites. Narrow-leaf Labrador-tea, cloudberry and Equisetum sylvaticum, which have cover values of 4-6%, also seem to prefer the cooler, wetter sites but none of these species are unique to this type. Floristically the type is most diverse during the 6-25-year post-fire period when it averages 41 species per stand; after that the number gradually declines to a low of 25 species/stand in the most mature group.

The thickness of the organic soil layer varies from 0 to an average of 15 cm (0-5.9 in), becoming progressively thicker with increased stand age. The amount of litter is very high initially and decreases steadily as the moss layer develops and as the numbers of broadleaf species decrease. The minimum depth of the active layer varies from 58-89 cm (23-35 in), the deeper values occurring during the 6-25 year period.

3) Succession in the Black Spruce/Lichen Stand Type: See Fig. 10. The dryness of the sites where this stand type occurs may be due to their topographic position, soil coarseness, or to some other factor. It can

Even though this type produces fewer willow than the aspen-black spruce stands, it is still an important type for willow production. Diamondleaf willow, grayish willow, and Hirtreiter willow all attain their greatest densities in this black spruce-willow type. Scum willow, Bobb willow, and feltleaf willow also occur.

A few additional species are less common but still important and should be mentioned. *Empetrum nigrum* has a cover of 5-25 in stands with a post-burn age of 5-25 years. This species seems to prefer the wettest sites, since it was also important in the aspen stand type. *Deschampsia flexuosa*, which has the same cover, seems to prefer the cooler, well-drained sites. *Harmonia* (L.) L. *clausenii* and *Empetrum nigrum*, which have cover values of 5-25, also seem to prefer the cooler, wetter sites but none of these species are unique to this type. Statistically the type is most diverse during the 5-25 year post-fire period when it averages 41 species per stand, after that the number gradually declines to a low of 25 species per stand in the next mature group.

The thickness of the organic soil layer varies from 0 to an average of 12 cm (0-5 in), becoming progressively thicker with increased stand age. The amount of litter is very high initially and decreases steadily as the moss layer develops and as the number of barefoot species decrease. The minimum depth of the active layer varies from 58-65 cm (23-25 in). The deeper values occurring during the 5-25 year period.

3) Succater in the Black Spruce/Aspen Stand Type: See Fig. 10. The dryness of the sites where this stand type occurs may be due to their topographic position, soil coarseness, or to some other factor. It can

occur on ridge tops, on the upper and middle slope positions on black spruce covered slopes, or in upland valleys. The black spruce/lichen type appears to prefer west-facing and southeast-facing slopes, though it is not restricted to them. The organic soil is 3-17 cm (1.2-6.7 in) thick. Frequently stones are intermixed with the mineral soil, making the determination of permafrost depths difficult. In the 51-100-year-old stands the active layer has a minimum depth of 76 cm (30 in), which is deep for black spruce stands of that age.

These stands appear more open than the others occurring on the dry/cool sites. Sometimes this is due to lower initial densities, other times it is due to the tip-over of trees. In either case open patches do exist. The lichens do very well in these more open areas.

Black spruce, bog blueberry, Calamagrostis spp., and Polytrichum spp. all occur with 50-100% frequency values at all stages, while Labrador-tea is slightly lower -- its values are between 40-90%. Rose is common the first five post-burn years; while fireweed, woodland horsetail, and Ceratodon purpureus are very frequent (frequency between 50-100%) during the first twenty-five years. Mountain-cranberry, crowberry and Pleurozium schreberi, Hylocomium splendens and Dicranum spp. are common.

It is the lichens that make this type distinctive. They first become important during the 26-50 year period. At this time the following species occur with frequencies above 50%: Cladina rangiferina, Cladina arbuscula, the unidentified Cladonia spp.-Cladonia species group, Cetraria islandica, Peltigera aphthosa, Peltigera canina, Parmelia spp., Usnea spp., and Alectoria spp. These, as well as Cetraria cucullata, Cetraria islandica, and Nephroma arcticum, occur in the mature black spruce/lichen stands.

occur on ridge tops, on the upper and middle slope positions on black spruce covered slopes, or in upland valleys. The black spruce/lichen type appears to prefer west-facing and southwest-facing slopes, though it is not restricted to them. The organic soil is 3-15 cm (1.5-6.3 in) thick. Frequently stones are intermixed with the mineral soil, making the determination of penetration quite difficult. In the 21-175-year-old stands the active layer has a minimum depth of 75 cm (30 in), which is deep for black spruce stands of that age.

These stands appear more open than the others occurring on the dry coal sites. Sometimes this is due to lower initial densities, either due to the tip-over of trees. In other cases open patches do exist. The lichens do very well in these more open areas.

Black spruce, bog blueberry, Calluna vulgaris, and Polytrichum

200. All occur with 50-100% frequency values at all stages. White Labrador tea is slightly lower -- its values are between 40-80%. Rose is common and first five post-burn years: white fireweed, woodland horsetail, and Calluna vulgaris are very frequent (frequency between 50-100%) during the first twenty-five years. Montanula canadensis, Crowberry and Pinguicula vulgaris, Urtica dioica and Potamogeton spp. are common.

It is the lichens that make this type distinctive. They first become important during the 20-50 year period. At this time the following species occur with frequency above 50%: Cladonia rangiferina, Cladonia arbuscula, the unidentified Cladonia species group, Cetraria islandica, Peltigera aphosa, Peltigera canina, Parma spp., and Alectoria spp. These, as well as Cetraria cucullata, Cetraria islandica, and Myurocladia, occur in the mature black spruce/lichen stands.

The total percent cover of lichens in this stand type is - 0%(0-5 years), 4%(6-25years), 32% (26-50 years), 21%(51-100 years), and 41% (>100 years). Since we did not study never-surveyed climax black spruce/lichen stands the data from the > 100 year category must be considered tentative as it comes from the climax mixed white spruce-black spruce/lichen type which occurred near timberline.

The black spruce/lichen type like the previous two stand types, is also an important willow producer. Scouler willow, diamondleaf willow, Bebb willow and grayleaf willow occur. Of these, Scouler willow seems to do best on this type of black spruce site.

Two other important species occur. Geocaulon lividum has an average cover of 2% and resin birch has over 1,000 stems/ha. Floristically this type becomes more diverse proportionally and directly as the stand age increases. Newly burned stands average 6 species/stand, the 6-25-year-old post-burn stands average 27 species, the 26-50-year-old stands average 36, the 51-100-year-old stands average 37, and the mature stands average 46 species/stand. The deadfall litter cover varies from 8-58% and frequency from 88-100%; the higher values occur when tall shrubs dominate the scene in the 6-25-year-old stands. Evidence of charred litter occurs through the first twenty-five years, though at the end of the period it is rare.

4) Succession in the Black Spruce/Labrador-tea/Equisetum sylvaticum Stand Type: See Figs. 23, 24C, 25C, 26C, and 12. This is probably the most common type occurring on black spruce sites. It appears to be transitional between the dry black spruce/lichen type and the wet black spruce/narrow-leaf Labrador-tea/Sphagnum type. Organic soil depth varies on

The total percent cover of *L. lucida* in this stand type is ~ 50 (0-8 years), 12 (0-25 years), 32 (26-50 years), 51 (51-100 years), and 41 (100+ years). Since we did not study newly-sprouted climax black spruce/white spruce stands the data from the ~ 100 year category must be considered tentative as it comes from the climax mixed white spruce-black spruce/white spruce type which occurred near Etah.

The black spruce/white spruce type like the previous two stand types, is also an important willow producer. Spouter willow, dominant willow, herb willow and grey willow occur. Of these, spouter willow seems to be best on this type of black spruce site.

Two other important species occur. *Salix glauca* is an average cover of 32 and *Salix glauca* has over 1,000 stems/m². This species type becomes more diverse proportionally and diversity as the stand age increases. Newly burned stands average 2 species/stand, the 0-25 year old post-burn stands average 3 species, the 26-50 year-old stands average 3, the 51-100 year-old stands average 3, and the mature stands average 4 species/stand. The deadfall litter cover varies from 0-5% and increases from 0-25 years; the higher values occur when tall shrubs dominate the scene in the 0-25 year-old stands. Evidence of cleared litter occurs through the first twenty-five years, though at the end of the period it is rare.

4) Succession in the black spruce/white spruce/white spruce/white spruce stand type: See Fig. 2A, 2B, 2C, 2D, 2E, and 2F. This is probably the most common type occurring on black spruce sites. It appears to be transitional between the dry black spruce/white spruce type and the wet black spruce/white spruce type. Organic soil depth varies on

the average from 3 to 18 cm (1.2-7 in). The minimum depth of the active layer averages 46 cm (18 in) in newly burned stands. Thawing increases for a period following fire until it reaches a maximum of 86 cm (34 in) in 6-25-year-old stands. Slowly this depth is reduced until once again the mature stands average 46 cm (18 in).

Black spruce, Labrador-tea, bog blueberry, mountain-cranberry and Calamagrostis spp. occur throughout the succession after 1 post-burn year with a frequency of more than 50%. Ceratodon purpureus is quite frequent during the 6-25-year period and Marchantia polymorpha has a high cover but low frequency at this time. Pleurozium schreberi Parmelia spp. and Cetraria pinastri have high frequencies during the 26-50-year period and thereafter; while Geocaulon lividum has a high cover during the 26-50-year period. Cloudberry, woodland horsetail, and Polytrichum spp. are frequent immediately after the fire, fade out, and then reappear beginning with the 51-100-year period. It appears that underground parts send up new shoots immediately after the fire but these fail to survive. It is only much later that the species reinvade the stand. Narrow-leaf Labrador-tea, Sphagnum spp., and Hylocomium splendens first attain high frequencies in the 51-100-year period; however, both of them already had attained high cover values in earlier stages.

For a treatment of the older than 100 year stage I have used the black spruce-white spruce/Labrador-tea/Geocaulon/Hylocomium-Pleurozium type which is not identical but similar. There, black spruce, rose, Labrador-tea, mountain-cranberry, Calamagrostis spp., woodland horsetail, Geocaulon lividum, Pleurozium schreberi, Hylocomium splendens, Parmelia spp. and Usnea spp. are species with high frequency values. Hylocomium

the average from 2 to 15 cm (1.5-7 in). The minimum depth of the active layer averaged 55 cm (19 in) in newly burned stands. Burning frequency for a period following this until it reached a maximum of 85 cm (33 in) in 5-15-year-old stands. Shallow soil depth is reduced until once again the mature stands average 45 cm (18 in).

Black spruce, Labrador-tea, bog blueberry, mountain-strawberry and *Calluna vulgaris* spp. occur throughout the succession after 1 post-burn year with a frequency of more than 50%. *Calluna vulgaris* is quite frequent during the 5-15-year period and *Calluna vulgaris* has a high cover but low frequency at this time. *Pinus strobus* is frequent in the 25-50-year period and *Calluna vulgaris* has high frequency during the 25-50-year period and thereafter while *Calluna vulgaris* has a high cover during the 25-50-year period. Cloudberry, woodland horsetail, and *Polytrichum commune* are frequent immediately after the fire, take out, and then disappear beginning with the 51-100-year period. It appears that underground parts need up and shoots immediately after the fire but these fail to survive. It is only much later that the species reinvade the stand. Narrow-leaf Labrador-tea, *Sphagnum* spp., and *Hylocomium splendens* first attain high frequencies in the 51-100-year period; however, both of them already had attained high cover values in earlier stages.

For a treatment of the other than 100 year stage I have used the black spruce-white spruce/Labrador-tea/Labrador-tea-*Pinus strobus* type which is not identical but similar. Thus, black spruce, rose, Labrador-tea, mountain-strawberry, *Calluna vulgaris* spp., woodland horsetail, *Pinus strobus*, *Pinus strobus*, *Hylocomium splendens*, *Polytrichum commune*, and *Betula* spp. are species with high frequency values.

splendens has higher cover values than Pleurozium schreberi.

This black spruce type is not a major producer of willow, even though all species mentioned in this report occur. Bebb willow is the densest during the willow-tall shrub stage (6-25 post-fire years), while diamond-leaf willow is the only one to still be present in the mature type.

This black spruce type does not support an extensive lichen cover though numerous Cladina spp., Cladonia spp., Peltigera spp., Nephroma spp., Cetraria spp. can sometimes occur in small amounts.

In work done in the Washington Creek study area, it appears that the black spruce/lichen type and this black spruce/Labrador-tea/Equisetum sylvaticum type combine to form a miniature mosaic.

Floristically this type becomes more diverse as the stand age increases. Young stands average 24 species while the mature ones average 37 species.

Litter (deadfall) cover ranges from 8-46%, with highest values occurring during the 6-25 year post-burn period.

5) Succession in the Black Spruce/Narrow-leaf Labrador-tea/Sphagnum Type: This type is found on cool, moist-wet sites. They are found most commonly on upland valley floors but can occur as patches on north-facing slopes as well. The organic layer is generally thick, ranging from 9 to over 40 cm (4-18 in), but averaging 25 cm (9.8 in). The minimum depth of the active layer averages 54 cm (21 in) in mature stands; however, in 1-5 year-old stands it is 120 cm (47 in) deep. Since data is somewhat incomplete for this type, it is possible that in some areas the active layer may drop even deeper during the 6-25-year post-fire period.

A few plant species like dwarf arctic birch, Andromeda polifolia L. (bog-rosemary), leatherleaf, Drosera rotundifolia L. (round-leaf sundew),

and Pinguicula villosa L. (hair butterwort) are unique to bogs. Other species, Sphagnum spp., Eriophorum vaginatum L. (cotton sedge tussocks), narrow-leaf Labrador-tea, bog cranberry, cloudberry and many sedges, although they occur on a variety of black spruce sites, do best on this wet one.

Black spruce is the main tree in this type.^{8/} Stands of black spruce on black spruce/narrow-leaf Labrador-tea/sphagnum sites are open, their densities will be less than those shown in the general description (mature stands will have less than 1,000 trees/ha).

The following species occur with frequencies above 50% in at least some of the age group stages found with this type: black spruce, bog blueberry, mountain-cranberry, narrow-leaf Labrador-tea, cloudberry, Labrador-tea, Calamagrostis spp., sedge, bog-cranberry, dwarf arctic birch, crowberry, Polytrichum spp., Ceratodon purpureus, Cladina rangiferina, Cladina arbuscula, unidentified Cladina spp. and Cladonia spp., Nephroma spp., and Parmelia. Resin birch, hare's tail grass, and bog cranberry are important, but occur with lower frequencies. It tentatively appears that floristically this type attains its greatest species count in the 6-25-year-old group when 39 species/stand can be expected. One five-year-old stand contained 16 species, while 100-year-old stands averaged 34 species per stand.

6) Succession on Young Scrapped Firelines: In ending this discussion I will make a few comments on how post-burn succession on scraped firelines differs from the unscraped burned stands. We surveyed three firelines

^{8/} Some stands on wet sites are dominated by larch. This is another community type and one that has yet to be studied.

and *Prunella villosa* L. (hair buttonwood) are unique to bogs. Other species, *Salix* spp., *Eriophorum vaginatum* L. (cotton edge tussock), narrow-leaf Labrador-tea, bog cranberry, cloudberry and many others, although they occur on a variety of black spruce sites, are best of this wet one.

Black spruce is the main tree in this type. ⁸ Stands of black spruce on black spruce/narrow-leaf Labrador-tea/alginate sites are open, their densities will be less than those shown in the general description (these stands will have less than 1,000 trees/ha).

The following species occur with frequencies above 50% in at least

some of the age group stands found with this type: black spruce, bog

blueberry, mountain-cranberry, narrow-leaf Labrador-tea, cloudberry,

Labrador-tea, *Calluna vulgaris* L., sedge, bog-cranberry, dwarf azalea

birch, crowberry, *Polytrichum* spp., *Carletonia purpurea*, *Cladonia rangiferina*,

Cladonia arbuscula, unidentified *Cladonia* spp., *Hebe* spp.

spp., and *Parthenocissus*. Rusty birch, hawthorn, tall grass, and bog cranberry

are important, but occur with lower frequencies. It tentatively appears

that floristically this type attains its greatest species count in the

6-25-year-old group when 23 species/stands can be expected. One five-

year-old stand contained 16 species, while 100-year-old stands averaged

34 species per stand.

6) Succession on young Scrapped Firline: In ending this discussion

I will make a few comments on how post-burn succession on scraped firline

differs from the unscraped burned stands. We surveyed three firlines

⁸ Some stands on wet sites are dominated by birch. This is another community type and one that has yet to be studied.

(see Fig. 29). Their ages ranged from 1-6 years and they will be treated as a group. With few exceptions all new growth starts from windblown seed, most underground plant parts having been scraped away. Black spruce, white spruce, birch and aspen seedlings were found. All these species were numerous, however more aspen seedlings occurred in aspen stands, more birch seedlings occurred in black spruce- hardwood stands, and more black spruce seedlings occurred in black spruce/ Labrador-tea/Equisetum sylvaticum stands. This is not surprising, for in each case the seed source and/or roots already existed on the site. Although most willow seedlings were too small for identification, diamondleaf willow and Scouler willow were identified. The density and development of all willows initially lags far behind their unscraped counterparts but in six years they are extremely dense. As many as 10,000 willow stems/ha may occur. Other tall and low shrub species found were rose, green alder, Labrador-tea, bog blueberry, mountain-cranberry, beauverd spiresa and raspberry. However, all were rare.

The herb species are better represented. Of the three most important species growing in the firelines, fireweed is more frequent than in the unscraped but burned stand. Woodland horsetail has more cover on the fireline than its counterpart nor on the fireline; and Calamagrostis spp. has lower average frequency and cover values on the fireline than in unscraped stands. A few other herbaceous species occur but are neither extensive nor common.

Two mosses, Polytrichum spp. and Ceratodon purpureus, dominate the moss layer and are more abundant on the firelines than in the unscraped stands. Other species may occur but in very small amounts. Lichens

(see Fig. 23). Their ages ranged from 1-5 years and they will be treated as a group. With few exceptions all new growth starts from rhizomes, and most underground plant parts having been scraped away. Black spruce, white spruce, birch and aspen seedlings were found. All these species were numerous, however more aspen seedlings occurred in aspen stands, more birch seedlings occurred in black spruce-herb stand, and more black spruce seedlings occurred in black spruce-Larix laricina stands. This is not surprising, for in each case the seed source and/or roots already existed on the site. Although most willow seedlings were too small for identification, diamondleaf willow and scurfy willow were identified. The density and development of all willow seedlings lagged far behind their unscrapped counterparts but in six years they are extremely dense. As many as 10,000 willow seedlings may occur. Other tall and low shrub species found were rose, green alder, Labrador-tea, bog blueberry, mountain-cheruberry, hawthorn, raspberry and currant. However, all were rare.

The herb species are better represented. Of the three most important species growing in the tundra, timothy is more frequent than in the unscrapped but burned stand. Woodland horsetail has more cover on the tundra than its counterpart now on the tundra; and *Calluna vulgaris* spp. has lower average frequency and cover values on the tundra than in unscrapped stands. A few other herbaceous species occur but are neither extensive nor common.

Two mosses, *Polytrichum* spp. and *Larix laricina*, dominate the moss layer and are more abundant on the tundra than in the unscrapped stands. Other species may occur but in very small amounts. Lichens

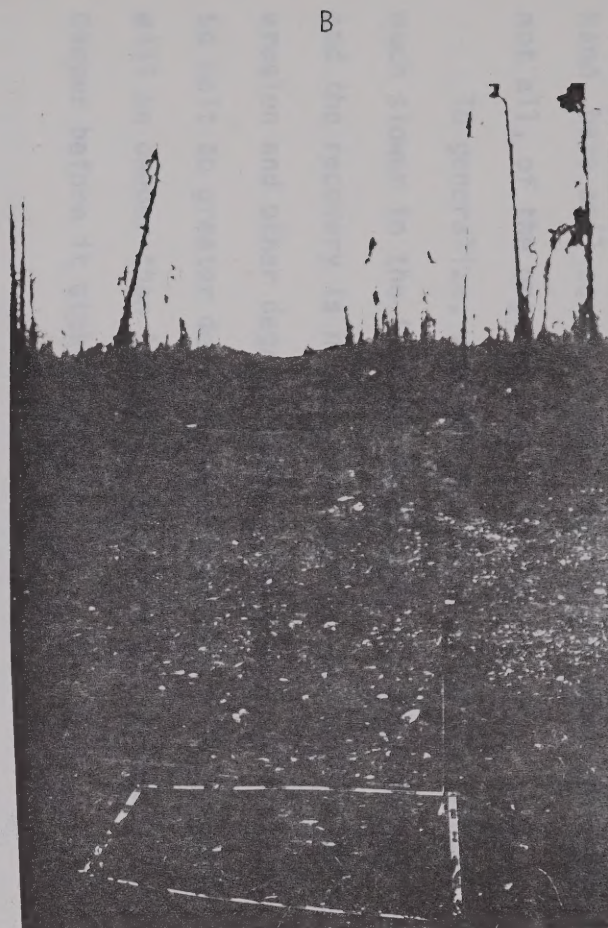
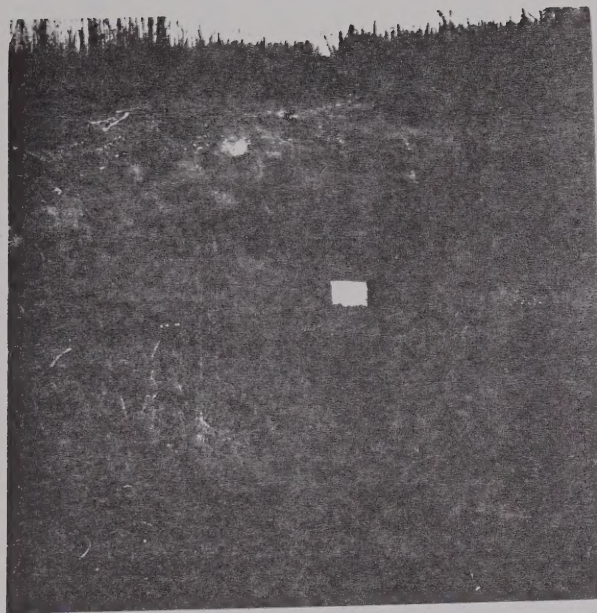


Figure 29.--Scraped firelines (1-6 years) on black spruce sites in interior Alaska. A: 4-year-old post-burn fireline (stand 192) with 26,000 tree seedlings, 10,000 willow, and 100 alder stems/ha, and an herb cover of 44%. B: 6-year-old post-burn fireline (stand 195) with over 4,000 tree seedlings, 2,000 willow, and 200 rose stems/ha and an herb cover of 3%.

are non-existent.

Amounts of deadfall litter are low (only 5% cover); dead wood cover averages only 2% cover, and charred ground covers only 4%. On the other hand, bare soil occurs frequently and averages 52% cover. Most, but not all, of the organic mat is removed.

To generalize, vegetative succession on the bladed firelines is much slower in the initial stages than in the unscrapped, but burned stands, and the recovery is highly dependent on the arrival of seeds. This allows erosion and other degradation processes to accelerate and permafrost to melt to greater depths. Four years after disturbance the active layer will be deeper than 150 cm (5 ft) on many firelines; and it may go much deeper before it stabilizes.

Some of these species occur on all three classes of climax sites, and some on only one type of climax site. They all differ in their frequency of occurrence, in their abundance, in their densities, and in the degree to which they are avoided. Since patterns associated with white spruce sites are somewhat different from those associated with black spruce sites, each was analyzed separately.

1. Discussion of White Spruce Sites Occurring on Climax White Spruce Sites. — Climax white spruce sites are important sources of food for browse animals. Fig. 30 shows the average stem density of all immature tree species (seedlings, saplings, and sucklings), all willow species, and all non-willow shrub species for stands where browse occurred. It also shows the average percent utilization of each of these categories.

are non-existent.

Amounts of deadfall litter are low (only 5% cover); dead wood cover averages only 2% cover, and charred ground covers only 4%. On the other hand, bare soil occurs frequently and averages 52% cover. Most, but not all, of the organic matter is removed.

To generalize, vegetative succession on the burned tundra is much slower in the initial stages than in the unscrubbed, out burned stands, and the recovery is highly dependent on the arrival of seeds. This allows erosion and other degradation processes to accelerate and permanent to melt to greater depths. Four years after disturbance the active layer will be deeper than 150 cm (5 ft) on many tundra; and it may go much deeper before it stabilizes.

D. Availability and Utilization of Browse Occurring on Upland Sites
Following Fire in Interior Alaska

Browse is any woody material which animals are likely to feed upon. Most often it is the tender young shoots of shrub and tree species which are less than 2.5 cm (1 in) in diameter, though older and larger material is sometimes utilized. In this study a total of 27 plant species showed some evidence of browse. They included 6 tree species - aspen, birch, balsam poplar, white spruce, black spruce, and larch; 6 willow species - Bebb, littletree, grayleaf, feltleaf, Scouler, diamondleaf, and unidentified ssp.; 4 non-willow tall shrub species - highbush cranberry, rose, resin birch, green alder, and thinleaf alder; and 11 low shrub species - bog blueberry, buffaloberry, Labrador-tea, beauverd spirea, red raspberry, low blueberry willow, shrubby cinquefoil, dwarf arctic birch, narrow-leaf Labrador-tea, leatherleaf, and crowberry.

Some of these species occur on all three classes of climax sites, and some on only one type of climax site. They all differ in their frequency of occurrence, in their abundance, in their densities, and in the degree to which they are browsed. Since patterns associated with white spruce sites are somewhat different from those associated with black spruce sites, each was analyzed separately.

1. Discussion of Woody Browse Species Occurring on Climax White Spruce Sites. -- Climax white spruce sites are important sources of food for browse animals. Fig. 30 shows the average stem density of all immature tree species (seedlings, saplings, and suckerlings), all willow species, and all non-willow shrub species for stands where browse occurred. It also shows the average percent utilization of each of these categories.

3. Availability and Utilization of Browse Occurring on Spruce Sites

Following Five in Interior Alaska

Browse is any woody material which animals are likely to feed upon.

Most often it is the tender young shoots of shrub and tree species which are less than 2.5 cm (1 in) in diameter, though older and larger material is sometimes utilized. In this study a total of 27 plant species showed some evidence of browse. They included 6 tree species - aspen, birch,

betula nana, white spruce, black spruce, and larch; 6 willow species -

Bush, hickory, gray, white, yellow, and unidentified

and 4 non-willow shrub species - highbush cranberry, rose, rose

hatch, green alder, and rhinoceros alder; and 11 low shrub species - dog

blueberry, tutsanberry, Labrador-tea, bearberry, red raspberry,

low blueberry willow, shrubby cineraria, dwarf arctic birch, narrow-leaved

Labrador-tea, leatherleaf, and crowberry.

Some of these species occur on all three classes of climax sites.

and some on only one type of climax site. They all differ in their fre-

quency of occurrence, in their abundance, in their density, and in

the degree to which they are browsed. Since patterns associated with

white spruce sites are somewhat different from those associated with

black spruce sites, each was analyzed separately.

1. Utilization of Woody Browse Species Occurring on Spruce Sites

Spruce Sites. — Climax white spruce sites are important sources of food

for browse animals. Fig. 30 shows the average stem density of all

tree species (seedlings, saplings, and sucklings), all willow species,

and all non-willow shrub species the stands where browse occurred. It

also shows the average percent utilization of each of these categories.

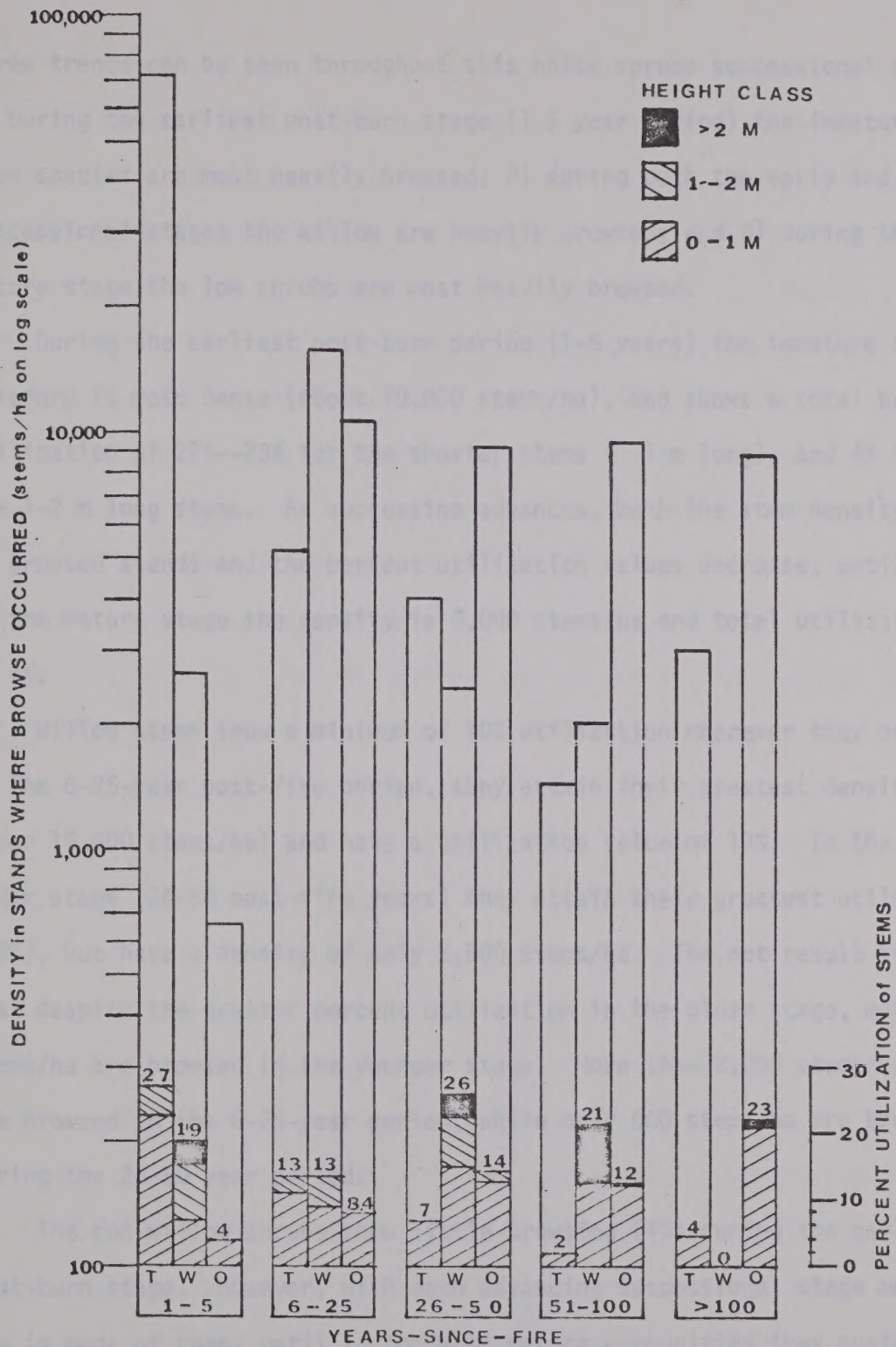


Figure 30.--Average browse availability and utilization on WS sites where browsing occurred. T=tree species (A, B, WS, BS, BP), W=willow species (Bebb, grayleaf, littletree, and unidentified), O=non-willow shrubs (green alder, rose, L-t, highbush cranberry, raspberry, buffalo-berry, and spirea).

Figure 30.—Average browse availability and utilization by WS sites where browsing occurred. Forage species (A, B, W, E, S, W, Willow species (B, E, S, W, and unidentified), Green willow shrubs (green aster, rose, L-f, highland cranberry, raspberry, buffalo-berry, and spruce).



Three trends can be seen throughout this white spruce successional series. 1) During the earliest post-burn stage (1-5 year period) the immature tree species are most heavily browsed; 2) during both the early and middle successional stages the willow are heavily browsed; and 3) during the mature stage the low shrubs are most heavily browsed.

During the earliest post-burn period (1-5 years) the immature tree category is most dense (about 70,000 stems/ha), and shows a total browse utilization of 27%--23% for the shorter stems (1 m long), and 4% for the 1-2 m long stems. As succession advances, both the stem density in browsed stands and the percent utilization values decrease, until in the mature stage the density is 3,000 stems/ha and total utilization is 4%.

Willow stems show a minimum of 10% utilization wherever they occur. In the 6-25-year post-fire period, they attain their greatest density (over 15,000 stems/ha) and have a utilization value of 13%. In the next older stage (26-50 post-fire years) they attain their greatest utilization (26%), but have a density of only 2,500 stems/ha. The net result is that despite the greater percent utilization in the older stage, more stems/ha are browsed in the younger stage. More than 2,000 stems/ha are browsed in the 6-25-year period, while only 600 stems/ha are browsed during the 26-50 year period.

The non-willow shrubs show little browsing (4%) during the early post-burn stage. However, with each advancing successional stage more use is made of them, until in the most mature communities they sustain over 20% utilization due to browsing.

Three trends can be seen throughout this white spruce successional series.

1) During the earliest post-burn stage (1-5 year period) the immature tree species are most heavily browsed; 2) during both the early and middle successional stages the willow are heavily browsed; and 3) during the mature stage the low shrubs are most heavily browsed.

During the earliest post-burn period (1-5 years) the immature tree category is most dense (about 70,000 stems/ha), and shows a total utilization of 51%--53% for the shorter stems (1 m long), and 4% for the 1-5 m long stems. As succession advances, both the stem density in browsed stands and the percent utilization values decrease, until in the mature stage the density is 3,000 stems/ha and total utilization is 4%.

Willow stems show a minimum of 10% utilization whenever they occur. In the 6-25 year post-fire period, they attain their greatest density (over 15,000 stems/ha) and have a utilization value of 13%. In the next older stage (26-50 post-fire years) they attain their greatest utilization (26%), but have a density of only 3,500 stems/ha. The net result is that despite the greater percent utilization in the older stage, more stems/ha are browsed in the younger stage. More than 5,000 stems/ha are browsed in the 6-25 year period, while only 600 stems/ha are browsed during the 26-50 year period.

The non-willow shrubs show little browsing (4%) during the early post-burn stage. However, with each advancing successional stage more use is made of them, until in the most mature communities they sustain over 50% utilization due to browsing.

Preference may be shown for certain browse species; the occurrence and utilization patterns of the species which compose the tree, willow and non-willow shrub categories do not appear to be positively correlated. Average densities for immature tree species found in stands where browse occurred ranged from 1,100-45,600 stems/ha for aspen, 700-108,900 stems/ha for birch, and 100-12,100 for all the remaining tree species. Utilization values ranged from 5-44% for aspen, 1-20% for birch and 1-5% for the rest of the trees. The average densities for willow species ranged from 2,000-26,100 stems/ha for Bebb willow, 16,800 for grayleaf willow, 3,100-5,600 for littletree willow and 100-2,100 for unidentified willows while the utilization values ranged from 13-21% for Bebb willow, 19% for grayleaf willow, and 5-27% for the unidentified willow group. The average densities for non-willow shrub species ranged from 600-17,000 stems/ha for rose, 200-25,200 stems/ha for Labrador-tea, 10,000-25,000 stems/ha for highbush cranberry, 9,400 stems/ha for beauverd spirea, and 800-9,600 stems/ha for the rest of the shrub species. Utilization values ranged from 6-57% for rose, 1-12% for Labrador-tea, 4-15% for highbush cranberry, 18% for beauverd spirea, and 2-4% for the rest. Table 6 shows the average availability and utilization values for all species, which, at some point in the successional series, have utilization values of at least 10%.

Young trees of both aspen and birch are utilized, especially in the earlier stages of succession. Values were 44% for aspen in the 1-5 year stage and 20% for birch in the 6-25 year period. At these times of heavy use most of the browsing (16-38%) occurs on the shorter stems, or on those less than 1 m; some use (2-6%) is made of the stems between 1-2 meters long; while the taller stems show little use (0-.2%).

Preference may be shown for certain browse species; the occurrence and utilization patterns of the species which compose the browse, willow and non-willow shrub categories do not appear to be positively correlated. Average densities for *Salix* spp. species found in stands where browse occurred ranged from 1,100-42,600 stems/ha for aspen, 700-108,900 stems/ha for birch, and 100-12,100 for all the remaining tree species. Utilization values ranged from 5-44% for aspen, 1-50% for birch and 1-5% for the rest of the trees. The average densities for willow species ranged from 2,000-28,100 stems/ha for *Salix* spp., 16,800 for grayleaf willow, 2,100-2,800 for *Salix* spp. and 100-2,100 for unidentified willows while the utilization values ranged from 13-57% for *Salix* spp., 10% for grayleaf willow, and 2-57% for the unidentified willow group. The average densities for non-willow shrub species ranged from 600-17,000 stems/ha for rose, 500-25,200 stems/ha for Labrador-tea, 10,000-25,000 stems/ha for highbush cranberry, 9,400 stems/ha for bearberry, and 600-9,400 stems/ha for the rest of the shrub species. Utilization values ranged from 5-57% for rose, 1-12% for Labrador-tea, 4-12% for highbush cranberry, 10% for bearberry, and 2-4% for the rest. Table 5 shows the average availability and utilization values for all species, which, at some point in the successional series, have utilization values of at least 10%. Young trees of both aspen and birch are utilized, especially in the earlier stages of succession. Values were 42% for aspen in the 1-2 year stage and 50% for birch in the 2-22 year period. At these stages of heavy use most of the browsing (15-35%) occurs on the shorter stems, or on those less than 1 m; some use (15-5%) is made of the stems between 1-2 meters long; while the taller stems show little use (0-5%).

Table 6. Average stem densities and stem utilization values for browsed species occurring in browsed stands found on climax white spruce sites in interior Alaska.

	Post-Burn-Year Categories									
	1-5		6-25		26-50		51-100		>100	
	Av.Den stems/ha	Percent Util.	Av.Den stems/ha	Percent Util.	Av.Den stems/ha	Percent Util.	Av.Den stems/ha	Percent Util.	Av.Den stems/ha	Percent Util.
Tree Species -										
<u>Populus tremuloides</u>	45,644	38-6-0	3,535	9-2-.2	5,974	10-0-0	2,125	5-0-0	1,126	5-0-0
<u>Betula papyrifera</u>	108,938	1-0-0	5,193	16-4-.2	NB		1,381	3-0-0	753	2-0-0
Other <u>2/</u>	NB	<u>1/</u>	12,100	5-0-0	125	1-0-0	1,250	2-0-0	NB	
Willow Species -										
<u>Salix bebbiana</u>	2,900	8-4-2	26,100	9-4-.2	2,100	17-2-0	2,000	13-0-8	NB	
<u>Salix glauca</u>	NB		NB		16,888	13-6-0	NB		NB	
<u>Salix arbusculoides</u>	NB		5,625	5-1-0	3,125	13-8-9	NB		NB	
<u>Salix species</u>	2,125	4-15-8	150	5-0-0	NB		NB		NB	
Other Shrub Species -										
<u>Rosa acicularis</u>	688	6-0-0	9,300	17-0-0	4,000	20-0-0	10,800	26-0-0	17,000	57-0-0
<u>Ledum groenlandicum</u>	500	1-0-0	25,200	12-0-0	6,600	3-0-0	(6,600)	1-0-0	250	5-0-0
<u>Viburnum edule</u>	NB		16,800	6-1-0	20,500	12-3-0	25,000	4-0-0	10,000	10-1-0
<u>Spiraea beauverdiana</u>	NB		NB		NB		NB		9,400	18-0-0
Other <u>3/</u>	NB		800	2-0-0	NB		NB		9,600	4-0-0

FOOTNOTES -

1/ NB = No Browse Recorded

2/ Other tree species include Populus balsamifera, Picea glauca, and Picea mariana. These species have utilization values of 0 - 7%.

3/ Other shrubs include Alnus crispa, Rubus idaeus, Shepherdia canadensis, and Vaccinium uliginosum. These species have utilization values of 0 - 9%.

Bebb willow is both the most utilized and the most abundant willow species. It reaches an averaged maximum density in browsed stands of more than 26,000 stems/ha during the 6-25 year period. At this time 13.2%, or 3,500 stems/ha, show browse marks. Its greatest percent utilization values occur in the next older stage when 19% of the stems, or 400 stems, were browsed. Grayleaf and littletree willows are less extensive than Bebb willow but are utilized as much or more when they occur. Grayleaf willow shows utilization values of 19% and littletree willow of 30%.

Rose, Labrador-tea, highbush cranberry, and beauverd spirea are the most utilized non-willow shrub species. Rose stems have a utilization value of 6% in the youngest stage; this value increases until in the mature stands 57% of the stems show browse marks. The greatest utilization of Labrador-tea (12%) occurred during the 6-25-year post-burn stage, the greatest utilization of highbush cranberry (15%) occurred during the 26-50-year post-burn stage, and the greatest utilization of beauverd spirea (18%) occurred during the most mature stage.

So far we have looked at how much browse material is available (density in stems/ha), and how much is actually utilized (% utilization). Another way to order the information is in terms of how common the species is (% frequency) in conjunction with how commonly the species is browsed. This information is combined in what I call the preference index obtained by the following calculation:

$$PI = \frac{\text{No. Stands Where Browse Occurred}}{\% \text{ Stands Where the Species Occurred}}$$

Some species occur rarely but whenever they do occur they are utilized by browsing animals. They could rank as high on this scale as do species

Such willow is both the most utilized and the most abundant willow
 species. It reached an averaged maximum density in burned stands of
 more than 25,000 stems/ha during the 5-25 year period. At this time
 12.5% or 3,500 stems/ha, show browse marks. Its greatest percent utiliza-
 tion values occur in the next older stage when 19% of the stems, or 400
 stems, were browsed. Grayleaf and Hottleberry willows are less extensive
 than willow but are utilized as much or more when they occur. Grayleaf
 willow shows utilization values of 19% and Hottleberry willow of 30%.
 Rose, Labrador-tea, nightshade cranberry, and bearberry species are
 the most utilized non-willow shrub species. Rose stems have a utilization
 value of 5% in the youngest stage; this value increases until in the
 mature stands 57% of the stems show browse marks. The greatest utilization
 of Labrador-tea (12%) occurred during the 5-25 year post-burn stage,
 the greatest utilization of nightshade cranberry (12%) occurred during
 the 25-50 year post-burn stage, and the greatest utilization of bearberry
 (18%) occurred during the most mature stage.
 So far we have looked at how much browse material is available (density
 in stems/ha), and how much is actually utilized (% utilization). Another
 way to order the information is in terms of how common the species is
 (% frequency) in conjunction with how commonly the species is browsed.
 This information is combined in what I call the preference index obtained
 by the following calculation:

$$PI = \frac{\text{No. Stems Where Browse Occurred}}{\text{No. Stems Where the Species Occurred}}$$

 Some species occur rarely but whenever they do occur they are utilized
 by browsing animals. They could rank as high on this scale as do species

which are both common and highly utilized. Conversely, those species which are rarely browsed would rank low on the scale regardless of the commonness of their occurrence. The following list gives the preference index values for each species by category:

Immature Tree Species -- Non-Willow Shrub Species --

Aspen	21	Blueberry	28
Birch	11	Rose	26
Balsam Poplar	6	Green Alder	25
White Spruce	5	Highbush Cranberry	23
Black Spruce	4	Buffaloberry	17
		Labrador-tea	15
Willow Species --		Spirea	7
Littletree	29	Raspberry	6
Grayleaf	29		
Bebb	26		
unidentified spp.	14		

In general those species high on the preference scale also have high utilization values. However, blueberry, green alder, and buffaloberry have high PI values and low average maximum utilization values (1%, 8%, & 4%, respectively). This suggests that even though some species are frequently sampled by the animals, little extensive use is made of them.

2. Discussion of Woody Browse Species Occurring on Climax Black Spruce Sites. -- Climax black spruce sites can also be important as a food source for browse animals. However, except for the earliest stages (1-25 years),

which are both common and highly utilized. Conversely, those species which are rarely browsed would rank low on the scale regardless of the commonness of their occurrence. The following list gives the preference index values for each species by category:

Temperate Tree Species --		Non-Temperate Tree Species --	
Aspen	51	Blueberry	23
Birch	11	Bass	25
Balsam Poplar	5	Green Alder	25
White Spruce	5	Highland Cranberry	23
Black Spruce	4	Buffaloberry	17
		Laborator-Tree	15
Willow Species --		Spruce	7
Litchberry	29	Raspberry	8
Grayleaf	29		
Bald	25		
unidentified spp.	14		

In general, those species high on the preference scale also have high utilization values. However, blueberry, green alder, and buffaloberry have high utilization values and low average maximum utilization values (13, 15, & 47, respectively). This suggests that even though some species are frequently sampled by the animals, little extensive use is made of them.

5. Discussion of Woody Browse Species Occurring on Elmer Black Spruce Tides. -- Elmer black spruce tides can also be important as a food source for browse animals. However, except for the earliest stages (1-25 years),

they seem less utilized than the climax white spruce sites. Figure 31 shows the average stem density of all immature tree species, all willow species, and all non-willow shrub species for stands where browse occurred, and average percent utilization made of each of these categories. Three trends are apparent throughout the successional series from 0-100 post-burn years: 1) Immature trees are highly utilized early in the successional series, their importance decreasing as succession advances. 2) Willows are most highly utilized during the 6-25 year period, declining in importance thereafter. 3) The non-willow shrubs, on the other hand, are little used in the younger stages, but as the succession advances their utilization increases. Two additional generalizations are possible: 1) Little occurs in the growing season which includes the fire; and 2) the pattern of use in stands older than 50 years is somewhat different from the patterns mentioned above. It would be interesting to know to what extent this difference is real, and to what extent this difference reflects the difference in composition of the older stage. As mentioned earlier in this report, most upland black spruce sites are burned before they attain post-burn ages of 100 years. Accordingly the older group of stands is composed largely of the wetter black spruce types and the mixed white spruce-black spruce site types.

During the 1-5 year post-burn period the immature tree species, especially aspen, are dense, averaging over 80,000/ha (See Fig. 31). They show a total browse of 29% -- 19% for the shorter stems, and 10% for the 1-2 meter long stems. Thereafter they decline in both total density and percent utilization, until in the 51-100 year post-burn stage they show only a 5% utilization.

they seem less utilized than the climax white spruce sites. Figure 31 shows the average stem density of all herbaceous tree species, all willow species, and all non-willow shrub species for stands where browse occurred, and average percent utilization made of each of these categories. Three trends are apparent throughout the successional series from 0-100 post-burn years: 1) limnane trees are highly utilized early in the successional series, their importance decreasing as succession advances; 2) willows are most highly utilized during the 0-25 year period, declining in importance thereafter; 3) the non-willow shrubs, on the other hand, are little used in the younger stages, but as the succession advances their utilization increases. Two additional generalizations are possible: 1) little occurs in the growing season which includes the fire; and 2) the pattern of use in stands older than 50 years is somewhat different from the patterns mentioned above. It would be interesting to know to what extent this difference is real, and to what extent this difference reflects the difference in composition of the older stage. As mentioned earlier in this report, most upland black spruce sites are burned before they attain post-burn ages of 100 years. Accordingly, the older group of stands is composed largely of the wetter black spruce types and the mixed white spruce-black spruce site types.

During the 1-5 year post-burn period the herbaceous tree species, especially aspen, are scarce, averaging over 60,000/ha (see Fig. 31). They show a local presence of 5% - 10% for the shorter stems, and 10% for the 1-5 meter long stems. Thereafter they decline in both total density and percent utilization, until in the 21-100 year post-burn stage they show only a 5% utilization.

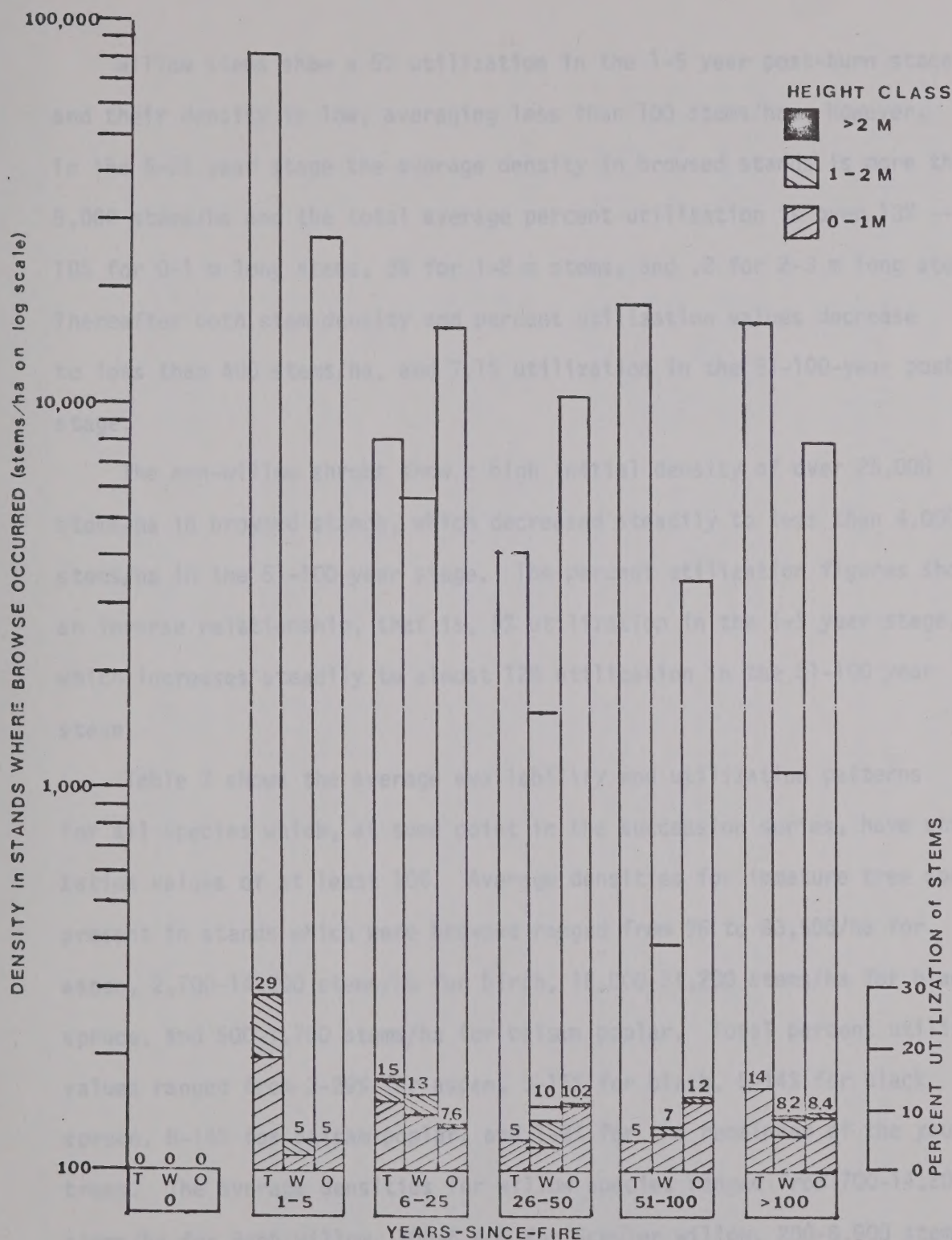


Figure 31.--Average browse availability and utilization on BS sites where browsing occurred. T=tree species, (A, B, WS, BS, BP, L), W=willow species (Bebb, Scouler, grayleaf, low blueberry, littletree, diamondleaf, feltleaf, and unidentified), O=non-willow shrub (thinleaf alder, green alder, Labrador-tea, rose, blueberry, raspberry, narrow-leaf Labrador-tea, dwarf arctic birch, resin birch, bush cinquefoil, and Viburnum).

HEIGHT CLASS

- > 2M
- 1-2M
- 0-1M

NUMBER OF PLANTS IN HEIGHT CLASS



Figure 11--Average browse availability and utilization on 95 sites where browsing occurred. T-tree species: A. B. W2, B2, W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W18, W19, W20, W21, W22, W23, W24, W25, W26, W27, W28, W29, W30, W31, W32, W33, W34, W35, W36, W37, W38, W39, W40, W41, W42, W43, W44, W45, W46, W47, W48, W49, W50, W51, W52, W53, W54, W55, W56, W57, W58, W59, W60, W61, W62, W63, W64, W65, W66, W67, W68, W69, W70, W71, W72, W73, W74, W75, W76, W77, W78, W79, W80, W81, W82, W83, W84, W85, W86, W87, W88, W89, W90, W91, W92, W93, W94, W95, W96, W97, W98, W99, W100. W-willow species: (B2, B3, B4, B5, B6, B7, B8, B9, B10, B11, B12, B13, B14, B15, B16, B17, B18, B19, B20, B21, B22, B23, B24, B25, B26, B27, B28, B29, B30, B31, B32, B33, B34, B35, B36, B37, B38, B39, B40, B41, B42, B43, B44, B45, B46, B47, B48, B49, B50, B51, B52, B53, B54, B55, B56, B57, B58, B59, B60, B61, B62, B63, B64, B65, B66, B67, B68, B69, B70, B71, B72, B73, B74, B75, B76, B77, B78, B79, B80, B81, B82, B83, B84, B85, B86, B87, B88, B89, B90, B91, B92, B93, B94, B95, B96, B97, B98, B99, B100. W-willow shrub (thinest shrub, green shrub, Labrador-tea, rose, blueberry, raspberry, narrow-leaf Labrador-tea, dwarf arctic birch, testin birch, bush cloudberry, and Viburnum).

Willow stems show a 5% utilization in the 1-5 year post-burn stage and their density is low, averaging less than 100 stems/ha. However, in the 6-25 year stage the average density in browsed stands is more than 5,000 stems/ha and the total average percent utilization is over 13% -- 10% for 0-1 m long stems, 3% for 1-2 m stems, and .2 for 2-3 m long stems. Thereafter both stem density and percent utilization values decrease to less than 400 stems/ha, and 7.1% utilization in the 51-100-year post-burn stage.

The non-willow shrubs show a high initial density of over 25,000 stems/ha in browsed stands, which decreased steadily to less than 4,000 stems/ha in the 51-100-year stage. The percent utilization figures show an inverse relationship, that is, 5% utilization in the 1-5 year stage, which increases steadily to almost 12% utilization in the 51-100 year stage.

Table 7 shows the average availability and utilization patterns for all species which, at some point in the succession series, have utilization values of at least 10%. Average densities for immature tree species present in stands which were browsed ranged from 96 to 83,500/ha for aspen, 2,700-14,200 stems/ha for birch, 19,000-21,200 stems/ha for black spruce, and 500-1,700 stems/ha for balsam poplar. Total percent utilization values ranged from 3-29% for aspen, 3-16% for birch, 5-14% for black spruce, 8-14% for balsam poplar, and 1-2% for the remainder of the young trees. The average densities for willow species ranged from 700-14,200 stems/ha for Bebb willow, 700-6,400 for Scouler willow, 200-8,900 stems/ha for the unidentified willow group, and 600-2,900 for the rest of the willows while; the total percent utilization values ranged from 6-34%

Willow stems show a 55 utilization in the 1-5 year post-burn stage and their density is low, averaging less than 100 stems/ha. However, in the 6-25 year stage the average density in browsed stands is more than 4,000 stems/ha and the total average percent utilization is over 13% -- 10% for 0-1 m long stems, 3% for 1-5 m stems, and 1% for 5-1 m long stems. Thereafter both stem density and percent utilization values decrease to less than 400 stems/ha, and 1% utilization in the 51-100 year post-burn stage.

The non-willow shrubs show a high initial density of over 25,000 stems/ha in browsed stands, which decreased steadily to less than 4,000 stems/ha in the 51-100 year stage. The percent utilization figures show an inverse relationship, that is, 5% utilization in the 1-5 year stage, which increases steadily to almost 15% utilization in the 51-100 year stage.

Table 1 shows the average availability and utilization patterns for all species which, at some point in the succession series, have utilization values of at least 10%. Average densities for mature tree species present in stands which were browsed ranged from 90 to 83,500/ha for aspen, 5,700-14,500 stems/ha for birch, 19,000-51,500 stems/ha for black spruce, and 500-1,700 stems/ha for balsam poplar. Total percent utilization values ranged from 3-25% for aspen, 3-16% for birch, 5-14% for black spruce, 8-14% for balsam poplar, and 1-5% for the remainder of the young trees. The average densities for willow species ranged from 100-14,500 stems/ha for Red Willow, 700-8,400 for Scouler willow, 500-8,000 stems/ha for the unidentified willow group, and 600-2,900 for the rest of the willows; the total percent utilization values ranged from 5-34%

Table 7. Average stem densities and stem utilization values for browsed species occurring in browsed stands found on climax black spruce sites in interior Alaska.

	Post-Burn-Year Categories									
	1-5		6-25		26-50		51-100		>100	
	Av.Den stems/ha	Percent Util.	Av.Den stems/ha	Percent Util.	Av.Den stems/ha	Percent Util.	Av.Den stems/ha	Percent Util.	Av.Den stems/ha	Percent Util.
Tree Species -										
<u>Populus tremuloides</u>	83,500	19-10-0	3,900	19-2-1	1,500	5-0-0	96	3-0-0		NB
<u>Betula papyrifera</u>	NB	1/	14,200	11-5-0	2,700	3-0-0	NB			NB
<u>Populus balsamifera</u>	NB		1,700	9-5-0	500	8-0-0	NB			NB
<u>Picea mariana</u>	NB		19,000	8-0-0	8,700	5-0-0	21,200	5-0-0	16,800	14-0-0
<u>Other 2/</u>	NB		7,300	2-0-0	300	1-0-0	NB			NB
Willow Species -										
<u>Salix bebbiana</u>	2,200	7-4-0	14,200	24-9-1	1,300	4-1-1	700	10-0-2		NB
<u>Salix scouleriana</u>	6,400	2-1-0	700	2-0-0	2,000	4-8-1	2,400	5-5-0		NB
<u>Salix unidentified spp.</u>	200	1-0-0	8,900	36-6-0	2,800	6-9-9	400	4-0-0		NB
<u>Other 3/</u>	1,100	1-0-0	2,900	3-4-0	600	2-1-0	500	2-0-0	2,900	6-1-1
Other Shrub Species -										
<u>Ledum groenlandicum</u>	95,300	7-0-0	56,500	10-0-0	21,400	10-0-0	(1,200) ^{5/}	3-0-0	1,200	2-0-0
<u>Rosa acicularis</u>	4,800	5-0-0	2,600	8-0-0	3,700	11-0-0	2,600	11-0-0	2,400	11-0-0
<u>Betula nana</u>	(3,000)	2-0-0	NB		NB		23,500	14-0-0		NB
<u>Betula glandulosa</u>	NB		20,500	6-1-0	9,200	11-1-0	10,800	4-0-0	19,800	11-1-0
<u>Alnus tenuifolia</u>	NB		7,000	2-13-0	NB		NB			NB
<u>Alnus crispa</u>	NB		800	2-0-0	4,400	8-3-0	2,700	12-5-1	8,100	6-1-0
<u>Other 4/</u>	3,200	3-0-0	22,000	5-0-0	6,000	6-0-0	2,300	4-0-0	(13,000)	5-0-0

FOOTNOTES -

- 1/ NB = no browse recorded
- 2/ Other tree species include white spruce and larch.
- 3/ Other willow species include Scouler, grayleaf, low blueberry, littletree, diamondleaf, and feltleaf willows.
- 4/ Other non-willow shrub species include thinleaf and viburnum as tall shrubs and shrubby cinquefoil, blueberry, raspberry, spirea, narrow-leaf labrador-tea, leatherleaf, and crowberry as low shrubs.
- 5/ () = density estimated from % cover values.

for Bebb willow, 2-13% for Scouler willow, 1-42% for the unidentified willow group, and 1-8% for the rest of the willows. The average densities for the non-willow shrubs ranged from 125 for raspberry to 95,000 for Labrador-tea, and utilization values varied from 1-18%.

Young aspen trees were browsed in the 1-5 year stage, while aspen, birch, black spruce, and balsam poplar were all browsed in the next older stage (22-29% for aspen, 16% for birch, 14% for balsam poplar, and 8% for black spruce). Most of the use (8-19%) occurs in the stems that are shorter than 1 m, some use (0-10%) is made of stems 1-2 m in length, while the longer stems show little use (0-1%).

Bebb willow is the most utilized willow species, however Scouler willow and the unidentified species group are also important. Bebb willow attains average densities of more than 14,000 stems/ha in the 6-25 year stage and at that time shows a total browse utilization of 39%. The highest willow densities occur during the 1-5 and 6-25 year stages, especially the latter. The highest percent utilization (39-42%) values occur during the 6-25 year period and, though they decline thereafter, they may stay above 10% even during the 51-100 year stage. Since the total density of willow species declines with time, the actual number of stems browsed is also decreasing as the post-burn stage becomes more advanced. For this site type, the 6-25 year period is the most important in terms of browse production and utilization.

Utilization of the non-willow shrub species as browse is somewhat sporadic. Labrador-tea, rose, dwarf arctic birch, resin birch, thinleaf alder, and green alder can all be important as food for browse animals. Labrador-tea shows utilization values ranging from 2-10%, the higher

for Red Willow, 5-12% for Scouler Willow, 1-4% for the unidentified Willow group, and 1-3% for the rest of the willows. The average densities for the non-willow shrubs ranged from 155 for raspberry to 95,000 for Labrador-tea, and utilization values varied from 1-18%.

Young aspen trees were browsed in the 1-2 year stage, white spruce, birch, black spruce, and balsam poplar were all browsed in the next older stage (25-50% for aspen, 10% for birch, 14% for balsam poplar, and 8% for black spruce). Most of the use (8-12%) occurs in the stems that are shorter than 1 m, some use (0-10%) is made of stems 1-2 m in length, while the longer stems show little use (0-1%).

Red Willow is the most utilized willow species, however Scouler Willow and the unidentified species group are also important. Red Willow attains average densities of more than 14,000 stems/ha in the 5-25 year stage and at that time shows a total browse utilization of 38%. The highest willow densities occur during the 1-5 and 5-25 year stages, especially the latter. The highest percent utilization (38-42%) values occur during the 5-25 year period and, though they decline thereafter, they may stay above 10% even during the 51-100 year stage. Since the total density of willow species declines with time, the actual number of stems browsed is also decreasing as the post-burn stage becomes more advanced. For this size type, the 5-25 year period is the most important in terms of browse production and utilization.

Utilization of the non-willow shrub species as browse is somewhat sporadic. Labrador-tea, rose, dwarf arctic birch, resin birch, thicket elder, and green alder can all be important as food for browse animals. Labrador-tea shows utilization values ranging from 2-10%, the higher

use occurring during the 6-25-year and 26-51-year stages. Rose, with utilization values ranging from .5-11%, and green alder with values ranging from 2-18%, are used most in the 26-50-year, 51-100-, and 100-year stages.

Thus far I have described how much browse material is available (density in stems/ha), and how much is actually utilized (% utilization). An additional statistic which may be used in judging degree of browsing is the preference index (PI). This index is calculated for each species by dividing the number of the stands in which browsing occurred by the percentage of the stands containing the species in question. The following list gives the preference index value for each species by category:

Immature Tree Species --		Non-Willow Tall Shrubs --	
Balsam Poplar	53	Highbush Cranberry	60
Aspen	31	Rose	53
Birch	20	Resin Birch	33
Black Spruce	16	Green Alder	27
Larch	13	Thinleaf Alder	9
White Spruce	10		
Willow Species --		Low Shrubs --	
Bebb	81	Low Blueberry Willow	50
Littletree	77	Shrubby Cinquefoil	40
Grayleaf	69	Labrador-tea	24
Feltleaf	60	Blueberry	22
Scouler	58	Dwarf Arctic Birch	15
Diamondleaf	38	Raspberry	14

was occurring during the 6-25-year and 26-51-year stages. Rose, with utilization values ranging from 2-12, and green alder with values ranging from 2-18, are used most in the 26-50-year, 51-100-, and 100-year stages.

Thus far I have described how much browse material is available (density in stands), and how much is actually utilized (2 utilization). An additional statistic which may be used in judging degree of browsing is the preference index (PI). This index is calculated for each species by dividing the number of the stands in which browsing occurred by the percentage of the stands containing the species in question. The following list gives the preference index value for each species by category.

Temperate Tree Species --		Non-Willow Tall Shrubs --	
Balsam Poplar	53	Highbush Cranberry	60
Aspen	31	Rose	52
Birch	20	Red Alder	22
Black Spruce	16	Green Alder	27
Larch	13	Thicket Alder	9
White Spruce	10		
Willow Species --		Low Shrubs --	
Geb	81	Low Blueberry Willow	50
Littleleaf	72	Shrubby Cinchona	40
Grayleaf	69	Lavender-leaf	54
Redleaf	60	Blueberry	52
Scouler	58	Sweet Arctic Birch	15
Gambelleaf	38	Raspberry	14

unidentified spp.	28	Spirea	12
		Narrow-leaf Labrador-tea	11
		Leatherleaf	9
		Crowberry	3

In general, those species which are high on the preference scale are also high in their percent utilization values. However, some species like, littletree willow, grayleaf willow, and blueberry are high on the preference scale, but utilization values are so low these species are not listed in Table 7. Although these species are browsed in many locations, amounts of plant material utilized are never large.

3. Comparing Browse Availability and Utilization on Climax White Spruce Sites and Climax Black Spruce Sites. -- Some generalizations from this initial survey can be made. 1) It appears that the general use trends are the same on both climax site types. That is, the immature trees are heavily utilized in the earliest successional stages, willows are heavily utilized during the next older stages, while non-willow shrubs are utilized most in the more mature stages.

2) It also appears that the species that are highly preferred on the white spruce sites are also preferred on the black spruce sites if they are found at all, and vice versa. Aspen, birch and balsam poplar are the preferred tree species; Bebb, littletree, and grayleaf willows are the preferred willow species; while highbush cranberry, rose, and green alder and the preferred non-willow shrub species. Bog blueberry is the only species to rank high in its preference index value for white spruce sites and low for the black spruce sites. Perhaps the browsers of bog blueberry are more common on white spruce sites than on black

15	Unidentified sp.	25	Cotton	15	Unidentified sp.
17	Narrow-leaf Labrador-tea	27	Leatherleaf	17	Narrow-leaf Labrador-tea
9	Crowberry	9	Leatherleaf	9	Crowberry
1		1		1	

In general, those species which are high on the preference scale are also high in their percent utilization values. However, some species like, *Triticale* willow, *grayleaf willow*, and *blueberry* are high on the preference scale, but utilization values are low. These species are not listed in Table 2. Although these species are present in many locations, amounts of plant material utilized are very large.

3. Comparing Brown Availability and Utilization on Black Spruce Sites and White Spruce Sites -- Some Generalizations from This Initial Survey can be made. 1) It appears that the general use trends are the same on both sites types. That is, the immature trees are heavily utilized in the earliest successional stages, willows are heavily utilized during the next older stages, while non-willow shrubs are utilized most in the more mature stages.

2) It also appears that the species that are highly preferred on the white spruce sites are also preferred on the black spruce sites. They are found at all, and vice versa. *Aspen*, *birch*, and *hudsonian poplar* are the preferred tree species; *Bebb*, *Triticale*, and *grayleaf willow* are the preferred shrub species; *white hudsonian cranberry*, *rose*, and *green alder* and the preferred non-willow shrub species. *Bog blueberry* is the only species to rank high in its preference index value for white spruce sites and low for the black spruce sites. Perhaps the presence of *bog blueberry* are more common on white spruce sites than on black

spruce sites.

3) The list of browsed species on black spruce sites has 28 species while the similar list for white spruce sites has 17 species. Buffalo-berry is unique to the white spruce list. Larch, feltleaf willow, Scouler willow, diamondleaf willow, resin birch, low blueberry willow, shrubby cinquefoil, dwarf arctic birch, narrow-leaf Labrador-tea, leatherleaf, and crowberry are unique to the list of browsed species occurring on black spruce sites. Most of these species which occur only on one of the lists are in fact unique to, or at least more common on, their respective site.

4) In terms of percent utilization, the browsed willow and non-willow shrub vegetation growing on upland white spruce sites may be more greatly utilized than that growing on upland black spruce sites. That is, on white spruce sites willow and non-willow shrub utilization values ranged from 0-26% and 4-22%, while on black spruce sites the corresponding values were 5-13% and 5-12%, respectively. However, conformation of these trends awaits statistical treatment.

5) In every case where a species occurs on both white spruce climax sites and on black spruce climax sites the preference index is higher, sometimes much higher, for the species when it occurs on the black spruce site. This suggests that the browse species are more commonly utilized on black spruce sites than on white spruce sites.

species sites.

2) The list of browned species on black spruce sites has 58 species while the similar list for white spruce sites has 17 species. *Betula*-berry is unique to the white spruce list. Larch, balsam poplar, scots pine, white spruce, black spruce, red spruce, white birch, low blueberry willow, shrubby willow, alder, narrow-leaved larch, narrow-leaved larch, leatherleaf, and crowberry are unique to the list of browned species occurring on black spruce sites. Most of these species which occur only on one of the lists are in fact unique to, or at least more common on, their respective sites.

3) In terms of percent utilization, the browned willow and non-willow shrub vegetation growing on upland white spruce sites may be more greatly utilized than that growing on upland black spruce sites. That is, on white spruce sites willow and non-willow shrub utilization values ranged from 0-50% and 4-100% while on black spruce sites the corresponding values were 0-100% and 0-100%, respectively. However, comparison of these trends needs statistical treatment.

4) In every case where a species occurs on both white spruce sites and on black spruce sites the preference index is higher, sometimes much higher, for the species when it occurs on the black spruce sites. This suggests that the brown species are more commonly utilized on black spruce sites than on white spruce sites.

E. Ignition Potential of the Forest Floor in Upland
Forest Types Occurring in Interior Alaska

The ignition potential of the forest floor is dependent on the amount of fuel present and the moisture content of the fuel when fire strikes. Fuel moisture hangs daily with the relative humidity of the air and is, in a general way, locally predictable when weather records of the preceeding week are available for the given area. The amount of fuel present reflects the accumulation over time of woody slash, standing deadfuel, litter, and organic matter within the stand. These components are measurable and can be estimated. In this study we attempted to estimate amounts of woody fuel and litter material present in upland stands.

The fuel type present reflects the type of stand where it was formed. Aspen and birch produce extensive leaf litter annually. In addition birch and aspen grow rapidly and their boles soon become free of branches close to the ground. This tends to make them relatively fire resistant. Conifers, especially black spruce, on the other hand, produce much less leaf litter annually. They grow more slowly, their main branches are closer together, more numerous, and quite divaricate. In addition, this mass of branch material stays on the tree for some time even after it has ceased to be functional. This dead material dries rapidly and makes the stand an excellent carrier of fire.

Because of these differences in fuel type and accumulation, the stand data were divided into the following groups for analysis: 1) Pure hardwood stands, 2) Pure black spruce stands, 3) Pure white spruce, 4) Hardwood-dominated mixed hardwood-spruce stands, and 5) Spruce-dominated mixed hardwood-spruce stands.

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Aspen and birch produce extensive leaf litter annually. In addition birch and aspen grow readily and their boles soon become free of branches close to the ground. This tends to make them relatively fire resistant. Conifers, especially black spruce, on the other hand, produce much less leaf litter annually. They grow more slowly, their main branches are closer together, more numerous, and quite divaricate. In addition, this mass of branch material stays on the tree for some time after it has ceased to be functional. This dead material dries rapidly and makes the stand an excellent carrier of fire.

Because of these differences in fuel type and accumulation, the stand data were divided into the following groups for analysis: 1) Pure hardwood stands, 2) Pure black spruce stands, 3) Pure white spruce, 4) Hardwood-dominated mixed hardwood-spruce stands, and 5) Spruce-dominated mixed hardwood-spruce stands.

Pure hardwood stands are those on which young hardwood trees are replacing old hardwood trees, and spruce, either live or dead, are rare. The hardwood types in our discussion are either aspen or birch stands types. These pure stands are not limited to, but are more extensive and common on climax white spruce sites.

Hardwood-dominated mixed hardwood-spruce stands are those where both hardwood trees and spruce trees occur or have occurred, but the former are the most prevalent tree component. These stands are common and may occur on either climax white spruce sites or on the drier climax black spruce sites.

Spruce-dominated mixed hardwood-spruce stands are those where both hardwood trees and spruce trees occur but the spruce trees are most prevalent. This type is common on climax black spruce sites and on some of the mature climax white spruce sites.

Pure spruce stands may or may not have young spruce replacing the older trees. The old spruce may be either dead or alive. Birch and aspen are rare, having survived the fire or post-dating the fire. Black spruce dominates on climax black spruce sites and in many climax mixed spruce sites, while white spruce dominated on climax white spruce sites.

As with the vegetation, the amount of fuel present in a stand will change as post-burn stand development occurs. Because of this the stands have been grouped into the same post-burn age-classes used in the vegetation analysis: 1-5 years, 6-25 years, 26-50 years, 50-100 years, and 100 years.

In the following discussion changes in fuel due to both overstory type and stand development stage will be considered. Each type of fuel will be treated separately.

Pure hardwood stands are those in which young hardwood trees are reflecting old hardwood trees, and spruce, either live or dead, are rare. The hardwood types in our discussion are either open or closed stands. These pure stands are not limited to, but are more extensive and common on climax white spruce sites.

Hardwood-dominated mixed hardwood-spruce stands are those where both hardwood trees and spruce trees occur or have occurred, but the former are the most prevalent tree component. These stands are common and may occur on either climax white spruce sites or on the drier climax black spruce sites.

Spruce-dominated mixed hardwood-spruce stands are those where both hardwood trees and spruce trees occur but the spruce trees are most prevalent. This type is common on climax black spruce sites and on some of the mature climax white spruce sites.

Pure spruce stands may or may not have young spruce reflecting the older forest. The old spruce may be either dead or alive. Black spruce are rare, having survived the fire or post-fire stage. Black spruce dominates on climax black spruce sites and in many climax mixed spruce sites, while white spruce dominates on climax white spruce sites. As with the vegetation, the amount of fuel present in a stand will

change as post-fire stand development occurs. Because of this the stands have been grouped into the same post-fire age-classes used in the vegetation analysis: 1-5 years, 6-25 years, 26-50 years, 51-100 years, and 100 years.

In the following discussion changes in fuel due to both overstory type and stand development stage will be considered. Each type of fuel will be treated separately.

1. Slash Fuel. --- Slash fuel is any woody material which is no longer alive or standing. It may lay in contact with the ground or it may be suspended above the ground. The size of the slash may vary from small twigs to large tree trunks. The size of the twigs, the volume of the slash and the height of the slash layer are all important in controlling fire temperature and the speed with which fire will move through a stand. Much of the following information is included in Table 8 and Figure 32.

1) Slash Fuel in Pure Hardwood Stands: Small diameter slash (.1-7.6 cm or .1-3 in) averages around 10 T/ha in the young post-burn stands and decreases steadily with increasing stand age until in the over-100-year-old age group it is about 1 T/ha (Table 8 and Fig. 32). In the 1-5-year post-burn period the volume of small ground fuel is slightly less (49%) than the small aerial fuel (51%), in the 6-100 year periods 30% is aerial and 70% is on the ground, and in the older than 100-year periods over 85% is on the ground and almost 15% is aerial. This increase in the amount of ground slash over aerial slash reflects the fact that even though most slash remains suspended above the ground for awhile, in time it collects on the ground.

The volume of large diameter slash (>7.6 cm or >3 in) varies (Table 8 and Fig. 32). In the 1-5 year post-fire period it averages 6 T/ha. In the 6-25 year period when more standing dead trees are falling this amount increases to over 23 T/ha. In the 26-50 year period the amount of large slash has decreased to around 1.4 T/ha. In the next stage, the 51-100 year period, it is even less, 1.1 T/ha. Apparently fire-killed trees are no longer a major source of new slash. Again in the older hardwood

Slash Fuel. — Slash fuel is any woody material which is no

longer alive or standing. It may lay in contact with the ground or it may be suspended above the ground. The size of the slash may vary from small chips to large tree trunks. The size of the slash, the volume of the slash and the height of the slash layer are all important in controlling fire temperature and the speed with which fire will move through a stand. Much of the following information is included in Table 8 and

Figure 32.

1) Slash Fuel in Pure Hardwood Stands: Small diameter slash (1-1.5

cm or 1-3 in) averages around 10 t/ha in the young post-fire stands and decreases steadily with increasing stand age until in the over-100-year-old age group it is about 1 t/ha (Table 8 and Fig. 32). In the 1-5-year post-fire period the volume of small ground fuel is slightly less (45%) than the small aerial fuel (51%), in the 6-100 year periods 50% is aerial and 50% is on the ground, and in the older than 100-year periods over 85% is on the ground and almost 100% is aerial. This increase in the amount of ground slash over aerial slash reflects the fact that even though most slash remains suspended above the ground for awhile, in time it collects on the ground.

The volume of large diameter slash (> 7.5 cm or 3 in) varies (Table

8 and Fig. 32). In the 1-5 year post-fire period it averages 6 t/ha. In the 6-50 year period when more standing dead trees are falling this amount increases to over 25 t/ha. In the 50-100 year period the amount of large slash has decreased to around 1.4 t/ha. In the next stage, the 101-150 year period, it is even less, 1.1 t/ha. Apparently fire-killed trees are no longer a major source of new slash. Again in the older periods

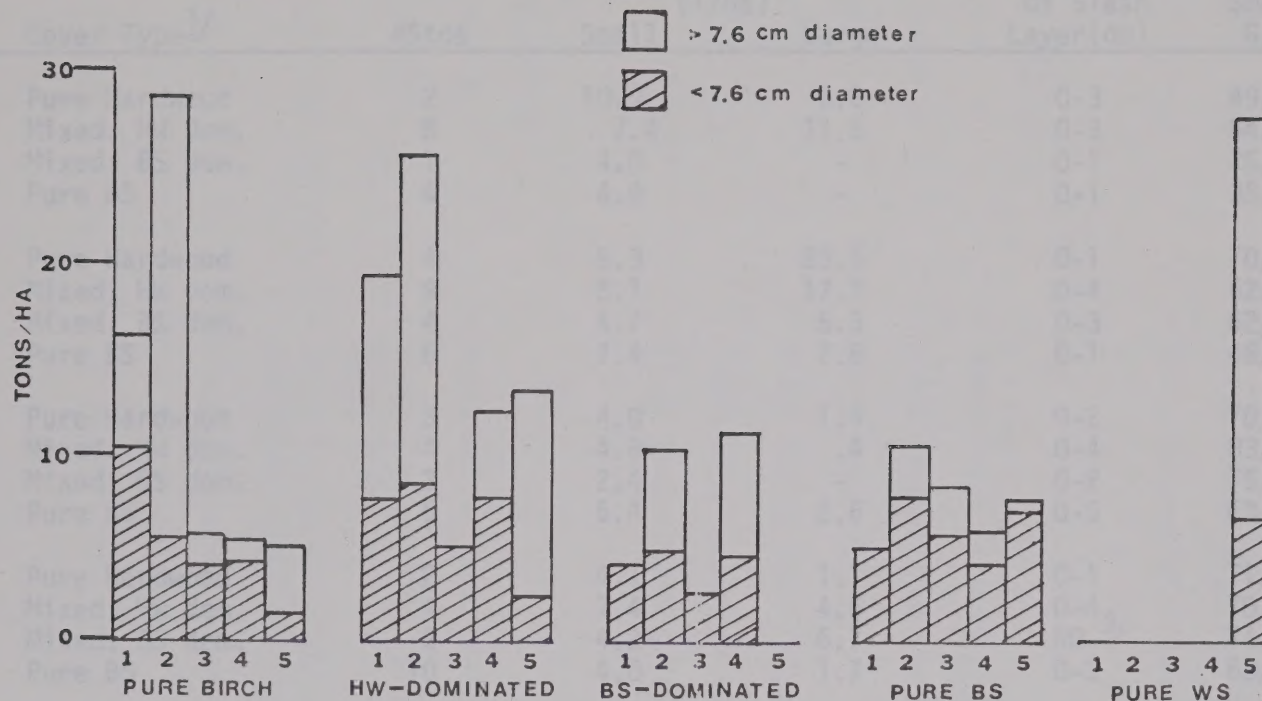


Figure 32.--Total slash fuel present in Pure birch stands, Hardwood--dominated mixed hardwood-spruce stands (HW-dominated), BS--dominated mixed hardwood-spruce stands (BS-dominated), Pure BS, and Pure WS. Columns 1-5 refer to post-fire-age of stand: 1 = 1-5 years, 2 = 6-25 years, 3 = 26-50 years, 4 = 51-100 years, 5 = >100 years.

Table 8. Slash production in different aged stands of 5 over story cover types occurring on upland slopes in interior Alaska.

Post-Burn Age-Class (Years)	Cover Type ^{1/}	#Stds	Volume of Slash (T/ha)		Height of Slash Layer(dm)	Distribution of Slash(%)	
			Small	Large		Small G/A ^{2/}	Large G/A
1-5	Pure Hardwood	2	10.3	6.0	0-3	49/51	100/0
	Mixed; HW dom.	8	7.4	11.8	0-3	54/46	19/81
	Mixed; BS dom.	1	4.0	-	0-1	25/75	
	Pure BS	4	4.9	-	0-1	35/65	
6-25	Pure Hardwood	4	5.3	23.5	0-1	70/30	61/39
	Mixed; HW dom.	9	8.1	17.7	0-4	52/48	57/43
	Mixed; BS dom.	4	4.7	5.3	0-3	62/38	53/47
	Pure BS	6	7.4	2.8	0-1	46/54	57/43
26-50	Pure Hardwood	3	4.0	1.4	0-2	70/30	29/71
	Mixed; HW dom.	4	4.8	.4	0-4	83/17	100/0
	Mixed; BS dom.	3	2.4	-	0-2	75/25	-
	Pure BS	5	5.4	2.6	0-5	63/37	100/0
51-100	Pure Hardwood	2	4.1	1.1	0-1	71/29	0/100
	Mixed; HW dom.	4	7.4	4.6	0-4	70/30	70/30
	Mixed; BS dom.	3	4.2	6.7	ND ^{3/}	74/26	64/36
	Pure BS	10	4.0	1.7	0-3	63/37	100/0
>100	Pure Hardwood	1	1.4	3.6	0-1	86/14	22/78
	Mixed; HW dom.	2	2.3	10.8	0-1	96/4	100/0
	Mixed; BS dom.	0	ND ^{3/}				
	Pure S; BS dom.	5	6.7	.6	0-4	28/72	0/100
	Pure S; WS dom.	5	6.2	20.9	0-1	37/63	79/21

FOOTNOTES:

^{1/} Community type names are abbreviated. Refer to the following page for their full names.

^{2/} G = ground; A = aerial; together the values add to 100%

^{3/} ND = no data

Key to Abbreviated Community Type Names

WS = White Spruce

- 1) A/VIB/T-F = Aspen/Viburnum/Twin-flower
- 2) B/VIB = Birch/Viburnum
- 3) WS/VIB/E. arv = White Spruce/Viburnum/Equisetum arvense
- 4) WS/T-F/E. syl = White Spruce/Twin-flower/Equisetum sylvaticum

BS = Black Spruce

- 5) A-BS/COR = Aspen-Black Spruce/Cornus
- 6) BS-A-B/CAL = Black Spruce-Aspen-Birch/Calamagrostis
- 7) BS/LIC = Black Spruce/Lichen
- 8) BS/R/PEL = Black Spruce/Rose/Peltigera
- 9) BS/L-T/E. syl = Black Spruce/Labrador-tea/Equisetum sylvaticum
- 10) BS/N-L L-T/SPH = Black Spruce/Narrow-leaf Labrador-tea/Sphagnum

MS = Mixed Spruce

- 11) B-WS-BS/CAL = Birch-White Spruce-Black Spruce/Calamagrostis
- 12) BS-WS/GW/HYL = Black Spruce-White Spruce/Grayleaf Willow/Hylocomium
- 13) BS-WS/L-T/GEO/HYL-PEL = Black Spruce-White Spruce/Labrador-tea/Geocaulon/Hylocomium-Pleurozium
- 14) BS-WS/LIC = Black Spruce/White Spruce/Lichen

Key to Abbreviated Community Type Names

W2 = White Spruce

- 1) W1B/T-F = Aspen/Viburnum/Infr-Flower
- 2) W1B = Birch/Viburnum
- 3) W1B/T-F = White Spruce/Viburnum/Infr-Flower
- 4) W1-T-F-F = White Spruce/Infr-Flower/Viburnum

B2 = Black Spruce

- 5) A-B2/COR = Aspen-Black Spruce/Cornus
- 6) B2-A-B2/CAL = Black Spruce-Aspen-Birch/Calamagrostis
- 7) B2/LIC = Black Spruce/Lichen
- 8) B2/RPBL = Black Spruce/Rose/Petioles
- 9) B2-L-T-F = Black Spruce/Labrador-Tax/Viburnum
- 10) B2-R-L-T-F = Black Spruce/Harrow-leaf/Labrador-Tax/Spangnum

M2 = Mixed Spruce

- 11) A-B2-B2/CAL = Birch-White Spruce-Black Spruce/Calamagrostis
- 12) B2-W2/WHYL = Black Spruce-White Spruce/Grayleaf Willow/Viburnum
- 13) B2-W2-L-T-F/RPBL = Black Spruce-White Spruce/Labrador-Tax/Viburnum/Petioles
- 14) B2-B2/LIC = Black Spruce-Black Spruce/Lichen

stands, where the mature trees are beginning to fall, the volume increases to an average of almost 4 T/ha.

Small-diameter fire-killed trees tend to fall sooner than the large-diameter fire-killed trees. After the first 25 post-fire years, 60-100% of the large slash is on the ground. Thereafter only 0-30% of it is on the ground. Perhaps the fire-killed ground-surface slash has become part of the thickening litter and decaying organic layers and the debris from the developing stand has not yet reached the ground.

The height of the slash layer ranges from 0-3 dm (0.1 ft) in the 1-5 post-burn period. Thereafter it varies from 0-2 dm (0-8 in) and is usually less than 1 dm (4 in) in height.

2) Slash Fuel in the Hardwood-Dominated Mixed Hardwood-Spruce Stands:

Small diameter slash weight averages just over 7 T/ha in the 1-5 year-old post-burn stands, and just over 8 T/ha in the 6-25 year-old stands (Table 8 and Figure 32). It decreases about 5 T/ha in the 26-50 year period; by this time most of the small fire-killed slash has already fallen. For the next 50 years (51-100 year period) the volume is higher, over 7 T/ha. This is the period when the post-fire trees are dense and undergoing self pruning. In the still older stands this self pruning has lessened and the decaying organic duff and litter layer is engulfing the older twig slash; the net result is that the volume of small slash is just over 2 T/ha. Throughout the first 25 post-fire years when the fire-killed trees are shedding litter, 50% of the small slash is ground slash and 50% is aerial slash. During the next 25 years, the 26-50-year period, when most of the fire-killed small slash has fallen, 80% of the slash is on the ground and 20% is aerial. In the next stage, the 51-100-

stands, where the volume trees are declining to fall, the volume increases to an average of almost 4 1/2%.

Small-diameter fire-killed trees tend to fall sooner than the large-diameter fire-killed trees. After the first 25 post-fire years, 50-100% of the large class is on the ground. Thereafter only 0-30% of it is on the ground. Perhaps the fire-killed ground-surface class has become part of the decomposing litter and decaying organic layers and the debris from the developing stand has not yet reached the ground. The height of the slash layer ranges from 0-3 dm (0-1 ft) in the 1-5 post-burn period. Thereafter it varies from 0-5 dm (0-2 ft) and is usually less than 1 dm (4 in) in height.

5) Slash Fuel in the Hardwood-Dominated Mixed Hardwood-Spruce Stands

Small-diameter slash weight averaged just over 7 t/ha in the 1-5 year-old post-burn stands, and just over 8 t/ha in the 6-25 year-old stands (Table 5 and Figure 3). It decreases about 2 t/ha in the 26-50 year period by this time most of the small fire-killed slash has already fallen. For the next 50 years (51-100 year period) the volume is higher, over 7 t/ha. This is the period when the post-fire trees are dense and undergoing self pruning. In the old-growth stands this self pruning has lessened and the decaying organic litter and litter layer is engulfing the older big slash; the net result is that the volume of small slash is just over 5 t/ha. Throughout the first 25 post-fire years when the fire-killed trees are shedding litter, 50% of the small slash is ground slash and 50% is aerial slash. During the next 25 years, the 26-50 year period, when most of the fire-killed small slash has fallen, 80% of the slash is on the ground and 20% is aerial. In the next stage, the 51-100-

year period when the pruning is occurring, 70% of the slash fuel is on the ground and 30% is aerial. With time, this aerial slash falls to the ground. In the greater than 100-year-old stands 95% of the slash is on the ground and only 5% is aerial. The slash accumulates faster than the developing litter and duff layers can incorporate it.

The larger diameter slash displays the same fluctuation in its volume and distribution as does the small diameter slash. In the 1-5 post-burn period amounts of large diameter slash total almost 12 T/ha -- 20% is on the ground and 80% is aerial (Table 8 and Figure 32). This increases to almost 18 T/ha in the 6-25-year period, when 60% is now on the ground and 40% aerial. It then drops to a low of .4 T/ha in the 26-50-year period when 100% is on the ground. This more or less ends the era of falling fire-killed trees and tree litter. In the 51-100 year period, the post-fire grown hardwood trees are beginning to fall, and as a result, the volume of large slash increases to almost 5 T/ha. While the hardwood trees continue to fall the volume of large slash increases to almost 11 T/ha. With time this large slash will be incorporated into the litter and duff layers.

The height of the slash layer varies from 0-4 dm (0-16 in). Throughout most of the succession it retains this range. However, in the mature stands of more than 100-year ages it is reduced to 0-1 dm (0-4 in).

3) Slash Fuel in the Conifer-Dominated Mixed Hardwood-Spruce Stands:

The volume of small slash in young stands of this type averages 4-5 T/ha for the first 25 post-fire years (Table 8 and Fig. 32). Initially, 25% of the amount is the ground slash and 75% is aerial slash, but in the next 20 years, during the 6-25-year period, this changes to 60% on

year period when the burning is occurring, 70% of the slash fuel is on the ground and 30% is aerial. With time, this aerial slash falls to the ground. In the greater than 100-year-old stands 55% of the slash is on the ground and only 45% is aerial. The slash accumulates faster than the developing litter and duff layers can incorporate it.

The larger diameter slash displays the same fluctuation in its volume and distribution as does the small diameter slash. In the 1-5 post-burn period amounts of large diameter slash total almost 15 T/ha -- 50% is on the ground and 50% is aerial (Table 2 and Figure 3). This increases to almost 18 T/ha in the 6-25-year period, when 50% is now on the ground and 50% aerial. It then drops to a low of 4 T/ha in the 26-50-year period when 100% is on the ground. This more or less ends the rise of falling thin-topped trees and tree litter. In the 51-100 year period, the post-fire grown hardwood trees are beginning to fall, and as a result, the volume of large slash increases to almost 3 T/ha. While the hardwood trees continue to fall the volume of large slash increases to almost 11 T/ha. With time this large slash will be incorporated into the litter and duff layers.

The height of the slash layer varies from 0-4 dm (0-16 in). Through-out most of the succession it remains this height. However, in the mature stands of more than 100-year age it is reduced to 0-1 dm (0-4 in).

3) Slash Fuel in the Conifer-Dominated Mixed Hardwood-Conifer Stands

The volume of small slash in young stands of this type averages 4-5 T/ha for the first 25 post-fire years (Table 3 and Fig. 3). Initially, 55% of the amount is the ground slash and 45% is aerial slash, but in the next 50 years, during the 6-25-year period, this changes to 80% on

the ground and 40% above the ground. During the following 25 years, in the 26-50 year post-fire period, when most of the fire-killed material has already become slash, the volume of small slash decreases to around 2 T/ha. In the next 50 years, the 51-100-year period, the volume of slash increases to about 4 T/ha. Natural pruning of the post-fire grown trees accounts for most of this increase. What occurs in more mature stands of this type is speculation since none of the stands surveyed fell into this category. However, it is most likely that the total volume of small slash will increase.

The amount of large slash occurring in the first 5 post-burn years is very small. Most of the trees remain standing or leaning but do not become slash. During the next 20 years, the 6-25 year period, the volume of large slash averages just over 5 T/ha (Table 8 and Fig. 32). No large slash was recorded for the next 25 year period, the 26-50-year post-burn age class. In the 51-100- year period once again large slash occurs; in fact, almost 7 T/ha was found. This may be attributed to the fact that the hardwood component is falling. With the dying of the hardwood component this type becomes less common. We studied no spruce-dominated mixed hardwood-spruce stands that were older than 100 years.

The height of the slash fuel ranges from 0-1 dm (0-4 in) in the early post-fire years. When most of the burned material is falling, during the 6-25-year period, the slash layer is 0-3 dm (0-1 ft) high. In the 6-25-year period it decreases to 0-2 dm (0-8 in) as more and more of the fire related material collects on the ground surface.

the ground and 40% above the ground. During the following 25 years, in the 25-50 year post-fire period, when most of the fire-killed material has already become slash, the volume of small slash decreases to around 2 t/ha. In the next 50 years, the 51-100 year period, the volume of slash increases to about 4 t/ha. Natural pruning of the post-fire growth trees accounts for most of this increase. What occurs in more mature stands of this type is speculation since none of the stands surveyed fell into this category. However, it is most likely that the total volume of small slash will increase.

The amount of large slash occurring in the first 5 post-burn years is very small. Most of the trees remain standing or leaning but do not become slash. During the next 50 years, the 5-25 year period, the volume of large slash averages just over 2 t/ha (Table 8 and Fig. 32). No large slash was recorded for the next 25 year period, the 26-50 year post-burn age class. In the 51-100 year period once again large slash occurs; in fact, almost 7 t/ha was found. This may be attributed to the fact that the hardwood component is falling. With the dying of the hardwood component this type becomes less common. We studied no spruce-dominated mixed hardwood-spruce stands that were older than 100 years.

The height of the slash foot ranges from 0.1 to 0.4 m in the early post-fire years. When most of the burned material is falling, during the 5-25 year period, the slash layer is 0.3 to 0.4 m high. In the 26-50 year period it decreases to 0.2 to 0.3 m (0.1 to 0.2 m) and more of the fire related material collects on the ground surface.

4) Slash Fuel in Pure Black Spruce Stands: The volume of small fuel is about 5 T/ha in 1-5-year-old post-burn stands, just over 7 T/ha in 6-25-year-old stands, about 5 T/ha in 26- 50-year-old stands, 4 T/ha in the 51-100-year-old stands, and almost 7 T/ha in the still older stands (Table 8 and Fig. 32). In the youngest stands 35% of the slash is on the ground. This increases to 65% in the 26-50-year post-burn period and remains at that level until new slash starts accumulating again in the older stands, then 30% is on the ground and 70% is aerial. The pattern of change is similar to that in the previously discussed black spruce-dominated mixed hardwood-spruce type, only the amounts change. In general, slightly more small slash occurs in this pure black spruce type than in the black spruce-dominated mixed hardwood-spruce stand type.

The large slash fuel follows a similar trend to that which occurred in the spruce-dominated mixed hardwood-spruce type. No large slash was recorded in the 1-5 post-burn period, just under 3 T/ha occurred in both the 6-25-year and 26-50-year periods, almost 2 T/ha occurred in the 51-100 year period, and .6 T/ha occurred in the still older stands (Table 8 and Fig. 32). In the 6-25-year period 60% of the slash is on the ground, in the 26-50-year and 51-100-year periods all of it is ground slash, and in the 100-year-old stands, where the post-fire grown trees start shedding slash, only 30% is ground slash.

The height of the slash fuel layers ranges from 0-1 dm in the first 25 post fire years, and in all the periods after that, 0-5 dm.

5) Slash Fuel in Pure White Spruce Stands: Pure white spruce stands seldom occur until the climax white spruce types are attained on older, undisturbed sites. Therefore this discussion is restricted to the

4) Slash Fuel in Pure Black Spruce Stands: The volume of small

fuel is about 2 t/ha in 1-5-year-old post-burn stands, just over 7 t/ha in 6-25-year-old stands, about 2 t/ha in 26-50-year-old stands, and about 5 t/ha in the still older stands in the 51-100-year-old stands, and about 7 t/ha in the still older stands (Table 8 and Fig. 32). In the youngest stands 85% of the slash is on the ground. This increases to 65% in the 26-50-year post-burn period and remains at that level until new slash starts accumulating again in the older stands, then 30% is on the ground and 70% is aerial. The pattern of change is similar to that in the previously discussed black spruce-dominated mixed hardwood-spruce type, only the amounts change. In general, slightly more small slash occurs in this pure black spruce type than in the black spruce-dominated mixed hardwood-spruce stand type.

The large slash fuel follows a similar trend to that which occurred in the spruce-dominated mixed hardwood-spruce type. No large slash was recorded in the 1-5 post-burn period, just under 3 t/ha occurred in both the 6-25-year and 26-50-year periods, almost 5 t/ha occurred in the 51-100-year period, and 8 t/ha occurred in the still older stands (Table 8 and Fig. 32). In the 6-25-year period 60% of the slash is on the ground, in the 26-50-year and 51-100-year periods 57% of it is ground slash, and in the 100-year-old stands, where the post-fire growth starts shedding slash, only 30% is ground slash.

The height of the slash fuel layers ranges from 0-1 dm in the first 25 post-fire years, and in all the periods after that, 0-2 dm.

5) Slash Fuel in Pure White Spruce Stands: Pure white spruce stands

seem occur until the climax white spruce type are attained on older, undisturbed sites. Therefore this discussion is restricted to the

>100-year period. At that time there is about 6 T/ha of small slash, almost 21 T/ha of large slash, and the height of the slash layer varies from 0-1 dm (0-4 in). Thirty percent of the small slash is on the ground, and 79% of the large slash is on the ground.

6) Comparing the Volume of Slash in Hardwood, Black Spruce, and White Spruce Stand Types: Figure 32 helps to visualize a comparison of the pure stand types. In the 1-5-year-old post-fire period pure birch stands have more slash fuel, both small and large diameter, than do pure black spruce stands (16.3-4.9 T/ha). Most of the fire-killed branches and twigs on the hardwood fall soon after a fire, while they are slower to fall in the black spruce stands.

In the 6-25-year-old post-fire period pure hardwood stands still have the most volume of slash fuel -- 28.8 T/ha (hw) vs. 10.2 T/ha (bs) -- however, most of it is of large diameter. Hardwood trees rot and fall earlier in the life of the stand than do black spruce trees. On the other hand, black spruce stands contain more small slash during this 6-25-year period than do the hardwood stands (7.4 T/ha for bs vs. 5.3 T/ha for hw).

In the 26-50, 51-100 and >100-year-old post-fire periods the pure black spruce stands have more slash fuel, both small and large, than do the hardwood stands. Total volumes for black spruce stands are 8.1, 5.7, and 7.3 T/ha, while for the hardwood stands they are 5.4, 5.2, and 5.0, respectively, in the 26-50, 51-100 and >100-year post-burn periods. The height of the slash fuel layer is highest in the young post-burn hardwood stands (0-3 dm) and decreases as the stands mature (0-1 dm), while in the black spruce stands just the reverse occurs. It is 0-1 dm

>100-year period. At that time there is about 5% of small slash, almost 5% of large slash, and the height of the slash layer varies from 0.1 to 0.4 in. Thirty percent of the small slash is on the ground, and 70% of the large slash is on the ground.

6) Comparing the Volume of Slash in Hardwood, Black Spruce, and

White Spruce Stand Types: Figure 32 helps to visualize a comparison

of the pure stand types. In the 1-5-year-old post-fire period pure black stands have more slash fuel, both small and large diameter, than do pure black spruce stands (15.3-4.9 t/ha). Most of the fire-killed branches end up on the hardwood fall soon after a fire, while they are slower to fall in the black spruce stands.

In the 6-15-year-old post-fire period pure hardwood stands still have the most volume of slash fuel -- 38.8 t/ha (hw) vs. 10.5 t/ha (bs) -- however, most of it is of large diameter. Hardwood trees rot and fall earlier in the life of the stand than do black spruce trees. On the other hand, black spruce stands contain more small slash during this 6-15-year period than do the hardwood stands (7.4 t/ha for bs vs. 5.3 t/ha for hw).

In the 16-30, 31-100 and >100-year-old post-fire periods the pure black spruce stands have more slash fuel, both small and large, than do the hardwood stands. Total volume for black spruce stands are 8.1, 2.7, and 1.3 t/ha, while for the hardwood stands they are 8.4, 5.5, and 5.0, respectively, in the 16-30, 31-100 and >100-year post-fire periods. The height of the slash fuel layer is highest in the young post-fire hardwood stands (0.3 dm) and decreases as the stands mature (0.1 dm) while in the black spruce stands just the reverse occurs. It is 0.1 dm

in the young post-burn stands and 0-5 dm in those which are older than 26 years.

Most of the slash in all black spruce stands is small slash, while in hardwood stands the ratio of large to small size slash varies. In the 1-5, 6-25 and 100-year-old stands the volume of large slash in hardwood stands is greater than the volume of small slash. These are periods when mature hardwood trees are most likely to fall. In 26-50 and 51-100-year-old stands the small slash in hardwood stands is greater than large slash. It is during this 26-100-year period that smaller trees, branches, etc. fall.

Stands of mixed hardwood-spruce composition display trends which are between these two. The hardwood-dominated stands are similar to the pure hardwood stands, and the spruce dominated stands are more similar to the pure black spruce stands with one exception. More large slash is produced in the 51-100-year period than might be expected. However, if one refers to the vegetation discussion, this is the period in which the aspen reach over-maturity and the birch undergo much thinning. In mixed stands where these species are disadvantaged, these slash producing processes are enhanced.

4) Mature white spruce stands have about the same volume of small slash (6 T/ha) as do the mature black spruce stands. However, the white spruce type has much more large slash than does the black spruce type -- 21 T/ha for white spruce and .6 T/ha for black spruce. Mature white spruce trees are usually of large diameter (25-28 cm or 9-11 in), black spruce trees are usually of a smaller diameter (6-12 cm or 2-5 in). This would account for the difference in the volume of large slash.

In the young post-burn stands and B-5 in those which are older than

25 years.

Most of the slash in all black spruce stands is small slash, while

in hardwood stands the ratio of large to small slash varies. In

the 1-5, 5-25 and 25-50 year-old stands the volume of large slash is

hardwood stands is greater than the volume of small slash. These are

periods when mature hardwood trees are most likely to fall. In 25-50

and 51-100 year-old stands the small slash in hardwood stands is greater

than large slash. It is during this 25-100 year period that smaller trees,

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it may refer to the vegetation distribution, this is the period in which

the aspect reach over-maturity and the birds undergo much thinning. In

mixed stands where these species are disadvantaged, there is less production

processes are advanced.

4) Mature white spruce stands have about the same volume of small

slash (5 tons) as do the mature black spruce stands. However, the white

spruce type has much more large slash than does the black spruce type --

21 tons for white spruce and 5 tons for black spruce. Mature white

spruce trees are usually of large diameter (25-50 cm or 8-17 in), black

spruce trees are usually of a smaller diameter (5-15 cm or 2-5 in).

This would account for the difference in the volume of large slash.

2. Standing Fuel. --- Standing fuel is any woody material which is standing and will burn if fire occurs. For the most part it is composed of dead, standing tree trunks and the dead branches which frequently are found on living trees. However, even living branches, especially spruce, will burn. Standing fuel is the means by which ground fires become crown fires. If one knows how close the smaller types of standing fuel are to the slash layer one can predict how likely fire is to travel into the crowns of trees. Therefore we measured the distance to lowest dead and the lowest living branches on the trees within the stands surveyed. Table 9 summarizes these data.

The standing dead trees, especially if fire-killed or wind smoothed, are soon devoid of bark and lower branches. They will burn but do not ignite easily.

In the first 5 post-burn years live trees and saplings are rare; those that do occur are relics which survived the fire. On the other hand, standing dead trees are common. During the next 20 years (6-25-year period) live saplings of aspen, birch will be common, especially in the hardwood types, and a few will be large enough to be called trees. Live spruce are fewer in number, but both saplings and trees occur. Many dead trunks of aspen, birch, and spruce are visible, many still standing but others are leaning or have become ground slash. During the next 25 years (26-50-year period) live saplings and trees of aspen, birch, and spruce are common. The standing dead trees, mostly black spruce still remain as burned relics of the fire-killed stand. During the next 50-year period (51-100 post-fire years) hardwood saplings become less numerous, but spruce and hardwood trees are common. Standing dead

3. Standing fuel --- Standing fuel is any woody material which is standing and will burn if fire occurs. For the most part it is composed of dead, standing tree trunks and the dead branches which frequently are found on living trees. However, even living branches, especially spruce, will burn. Standing fuel is the means by which ground fires become crown fires. If one knows how close the smaller types of standing fuel are to the slash layer one can predict how likely fire is to travel into the crowns of trees. Therefore we measured the distance to lowest dead and the lowest living branches on the trees within the stands surveyed. Table 2 summarizes these data.

The standing dead trees, especially if fire-killed or wind snuffed, are seen devoid of bark and lower branches. They will burn but do not ignite easily.

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Table 9. The minimum height of the small diameter standing fuel layer occurring in different aged stands of 5 overstory cover types occurring on upland slopes in interior Alaska.

Distance to Lowest Branch (DM)

Post-Burn Stand		Dead Branches on			Live Branches on	
Age Class (Years)	Cover Type ^{1/}	#Stds	Trees	Saplings	Trees	Saplings
1-5	Pure Hardwood	2	E-20 ^{2/}	N	E-80	2 dm
	Mixed; HW dom.	8	E-20 ^{2/}	N	E-80(HW)	1(HW)
	Mixed; BS dom.	1	N ^{3/}	N	N	N
	Pure BS	4	N	N	N	N
6-25	Pure Hardwood	4	E-10	E-3	E-15	E-10
	Mixed; HW-BS ^{4/}	9	4-10(HW)	3(HW)	14-26(HW)	17(HW)
	" " "	4	3-(S)	E-1(S)	E-5(S)	E-1(S)
	Pure BS	6	2		7	
26-50	Pure Hardwood	3	E-20	E-10	E-20	E-10
	Mixed; HW-BS	4	E-20(HW)	10(HW)	> 20(HW)	E-10
	" " "	3	3(S)	2(S)	15(S)	7(S)
	Pure BS	5	3	2	8	6
51-100	Pure Hardwood	2	> 20	E-10	> 20	E > 10
	Mixed; HW-BS	4	E > 20(HW)	E > 20(HW)	23(HW)	E > 10
	" " "	3	3(S)	3(S)	12(S)	4-8(S)
	Pure BS	10	2	1	9	6
> 100	Pure Hardwood	1	> 20	N	88	N
	Mixed; HW-BS	2	14(HW)	13(HW)	38(HW)	28(HW)
	" " "	0	E-3(S)	E-3(S)	E-3(S)	3(S)
	Pure BS	5	3	E-3	25	E-3(S)
	Pure WS	5	8	E-5	54	E-5

FOOTNOTES:

^{1/} Community type names are abbreviated. Refer to the following page for their full names.

^{2/} E = value is estimated

^{3/} N = no trees or saplings occur

Key to Abbreviated Community Type Names

WS = White Spruce

- 1) A/VIB/T-F = Aspen/Viburnum/Twin-flower
 2) B/VIB = Birch/Viburnum
 3) WS/VIB/E. arv = White Spruce/Viburnum/Equisetum arvense
 4) WS/T-F/E. syl = White Spruce/Twin-flower/Equisetum sylvaticum

BS = Black Spruce

- 5) A-BS/COR = Aspen-Black Spruce/Cornus
 6) BS-A-B/CAL = Black Spruce-Aspen-Birch/Calamagrostis
 7) BS/LIC = Black Spruce/Lichen
 8) BS/R/PEL = Black Spruce/Rose/Peltigera
 9) BS/L-T/E. syl = Black Spruce/Labrador-tea/Equisetum sylvaticum
 10) BS/N-L L-T/SPH = Black Spruce/Narrow-leaf Labrador-tea/Sphagnum

MS = Mixed Spruce

- 11) B-WS-BS/CAL = Birch-White Spruce-Black Spruce/Calamagrostis
 12) BS-WS/GW/HYL = Black Spruce-White Spruce/Grayleaf Willow/Hylocomium
 13) BS-WS/L-T/GEO/HYL-PEL = Black Spruce-White Spruce/Labrador-tea/Geocaulon/Hylocomium-Pleurozium
 14) BS-WS/LIC = Black Spruce/White Spruce/Lichen

Key to Abbreviated Community Type Names

W2 = White Spruce

- 1) A/VB/T-F
- 2) B/VB
- 3) W/VB/E
- 4) W/T-T/E

- = Aspen/Viburnum/Twin-Flower
- = Birch/Viburnum
- = White Spruce/Viburnum/Tanacetum arvensis
- = White Spruce/Twin-Flower/Tanacetum arvensis

B2 = Black Spruce

- 5) A-B2/COR
- 6) B2-A-B2/CAL
- 7) B2/CIC
- 8) B2/PPEL
- 9) B2/E-T/E
- 10) B2/E-L-T/SPH

- = Aspen-Black Spruce/Cornus
- = Black Spruce-Aspen-Birch/Calamagrostis
- = Black Spruce/Lichen
- = Black Spruce/Rose/Polemonium
- = Black Spruce/Labrador-Tea/Tanacetum arvensis
- = Black Spruce/Birch-Tea/Labrador-Tea/Sphagnum

M2 = Mixed Spruce

- 11) B-B2-B2/CAL
- 12) B2-W2/B2/W/T
- 13) B2-W2/L-T/SPH/PPEL
- 14) B2-W2/CIC

- = Birch-Mixed Spruce-Black Spruce/Calamagrostis
- = Black Spruce-Mixed Spruce/Birch/Tea/Willow/Hypoxis
- = Black Spruce-Mixed Spruce-White Spruce/Labrador-Tea/Gaultheria/Prostrata-Flax
- = Black Spruce-Mixed Spruce/Lichen

trees occur but are not as common as in the earlier post-fire years. After 100 years hardwood saplings and aspen trees are rare while birch, black spruce and white spruce trees are common. Standing dead birch and spruce trees occur only sporadically.

1) Standing Fuel in Hardwood Stands: Dead, standing snags or tree trunks may remain standing for some time after the fire. However, most become slash within the first twenty-five post-fire years. Most of the hardwood trunks are devoid of small branches at least for some distance (60-90 dm or 20-30 ft) above the ground. In the 6-25-year period when the post-fire grown trees reach sapling size, an occasional dead branch may be as low as 3 dm (1 ft) above the ground, and the live branches start at 15 dm (5 ft). As trees grow rapidly, dead branches are shed from at least the lower 20 dm (7 ft) and the trunks remain smooth and relatively fire resistant.

2) Standing Fuel in Spruce Stands: Dead, standing spruce snags are common following fire. Many fall within the first 25 post-fire years, yet numerous snags are still visible in the older stands. Where the fire was intense most of the dead trees are devoid of small branches but where burning was light or the trees merely scorched, many branches and even some needles remain. Trees in this condition, when dry, are highly flammable.

Post-fire grown trees are slow to develop -- few attain even sapling status within the first 5 post-fire years. Where they do occur dead branches can be found within 3 dm (1 ft) of the ground on both saplings and trees.

In 26-50-year-old stands the lowest live black spruce branches are

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black spruce and white spruce trees are common. Standing dead birch
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but where burning was light or the trees merely scorched, many branches
and even some needles remain. Trees in this condition, when dry, are
highly flammable.

Post-fire grown trees are slow to develop -- few attain even sapling
status within the first 25 post-fire years. Where they do occur dead
branches can be found within 3 dm (1 ft) of the ground on both saplings
and trees.
In 25-50-year-old stands the lowest live black spruce branches are

within 8 dm (2.5 ft) of the ground on trees and within 6 dm (2 ft) on saplings. In the oldest black spruce stands dead branches begin within 3 dm (1 ft) of the ground and continue up the trunk while the live branches may start as high as 25 dm (9 ft) above ground level. These trees can be highly flammable.

White spruce trees grow faster than most black spruce trees. However, even in mature white spruce stands dead twigs may often occur within 8 dm (2.5 ft) of the forest floor and will continue to occur along the stem. Live branches may start 15-55 dm (5-18 ft) above the ground.

Spruce trees are much more flammable than hardwood trees. In mixed stands the amount of standing fuel present falls somewhere between the two extremes. The more spruce present, the more flammable they are at all ages.

3. Non-Woody Forest Floor Fuels. --- So far the discussion has considered woody fuels occurring within the forest. Leaf litter, moss litter, lichen litter as well as the living moss and lichen layers can be important types of fuel, especially when they are dry. Both the amount of litter and the types of litter vary with the stand. Table 10 summarizes information on litter types.

This litter, along with the woody fuels, are the undecomposed components of the organic layer on the forest floor. Therefore the cross-section of the organic layer is a record of past and present litter and fuel production. This layer when sufficiently dry, will readily burn and help a fire to spread.

1) Non-Woody Fuels in Hardwood Stands: The only non-woody litter type to occur in this type of stand is leaf litter which will be 2-3 cm

within 6 m (20 ft) of the ground on trees and within 6 m (20 ft) on saplings. In the oldest black spruce stands dead branches begin within 3 m (10 ft) of the ground and continue up the trunk while the live branches may start as high as 25 m (80 ft) above ground level. These trees can be highly flammable.

White spruce trees grow faster than most black spruce trees. However, even in mature white spruce stands dead twigs may often occur within 8 m (25 ft) of the forest floor and will continue to occur along the stem. Live branches may start 15-25 m (50-75 ft) above the ground. Spruce trees are much more flammable than hardwood trees. In mixed stands the amount of standing fuel present falls somewhere between the two extremes. The more spruce present, the more flammable they are at all ages.

3. Non-Woody Forest Floor Fuels. -- So far the discussion has considered woody fuels occurring within the forest. Leaf litter, moss, lichen, lichen litter as well as the living moss and lichen layers can be important types of fuel, especially when they are dry. Both the amount of litter and the type of litter vary with the stand. Table 10 summarizes information on litter types.

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Table 10. Depth of litter and total organic thickness in different aged stands of 5 overstory cover types occurring on upland slopes in interior Alaska.

Post-Burn Stand		#Stds	Litter Type and Thickness in cm				Thickness of Total Organic Layer(cm)
Age Class	Cover Type		Broadleaf	Green Moss	Brown Moss	Lichen	
1-5	Pure Hardwood ^{1/}	2	2-3	N ^{2/}	N	N	3-5
	Mixed; HW dom.	2	.5	N	N	N	4-8
	Mixed; BS dom.	7	.6	.7	6	N	8-12
	Pure BS	9	N	.8	5	N	3- >20
6-25	Pure Hardwood	4	4-8	N	N	N	5-12
	Mixed; HW dom.	5	.5-2	N	N	N	2-12
	Mixed; BS dom.	8	2-3	1-2	2-9	N	8-16
	Pure BS	6	3	2	5	2-6	9-12
26-50	Pure Hardwood	3	5-6	N	N	N	4-9
	Mixed; HW dom.	1	4	1	1	N	7-12
	Mixed; BS dom.	6	3	.3-6	2-13	5	6-17
	Pure BS	5	N	7	8	6	16-21
51-100	Pure Hardwood	2	ND	N	N	N	10-13
	Mixed; HW dom.	2	7	1	1	N	12
	Mixed; BS dom.	5	3	2	2	ND	15
	Pure BS	9	N	3-6	9-17	6	16- >34
>100	Pure Hardwood	1	4	N	N	N	13
	Mixed; HW dom.	2	4	1	1	N	13
	Mixed; BS dom.	4	2	6	9	8	16
	Pure S; BS dom.	1	N	6	ND	ND	17
	Pure S; WS dom.	5	2	6-7	7-9	ND	8-12

FOOTNOTES:

^{1/} Community type names are abbreviated. Refer to the following page for their full names.

^{2/} N = not found

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 3) WS/VIB/E. arv = White Spruce/Viburnum/Equisetum arvense
 4) WS/T-F/E. syl = White Spruce/Twin-flower/Equisetum sylvaticum

BS = Black Spruce

- 5) A-BS/COR = Aspen-Black Spruce/Cornus
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 10) BS/N-L L-T/SPH = Black Spruce/Narrow-leaf Labrador-tea/Sphagnum

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 3) WS/VB-E = White Spruce/Viburnum/Equisetum arvense
 4) WS/VB-L = White Spruce/Viburnum/Lupinus sylvaticus

BS = Black Spruce

- 5) A-BS/CB = Aspen-Black Spruce/Cornus
 6) BS-A-B/CAL = Black Spruce-Aspen-Birch/Calamagrostis
 7) BS/LIC = Black Spruce/Lichen
 8) BS/VB-EI = Black Spruce/Viburnum/Equisetum
 9) BS/L-T/E = Black Spruce/Labrador-Tea/Equisetum sylvaticum
 10) BS/L-L-T/SPH = Black Spruce/Labrador-Tea/Sphagnum

WS = Mixed Spruce

- 11) B-WS-BS/CAL = Birch-White Spruce-Black Spruce/Calamagrostis
 12) BS-WS/BW/L = Black Spruce-White Spruce/Betula/Lupinus
 13) BS-WS-L-V/SPH-T/L = Black Spruce-White Spruce/Labrador-Tea/Sphagnum
 14) BS-WS/LIC = Black Spruce-White Spruce/Lichen

(.8-1.2 in) thick in young stands (1-5-years-old), 4-8 cm thick in the tall shrub and dense hardwood stages (6-25-year and 26-50 year periods), and at least 4 cm (1.6 in) thick in mature stands (100-year-stands).

In the young stands the organic layer is 3-5 cm (1.2-2 in) thick, and mostly composed of leaf litter. The organic layer gradually thickens as the stand age increases until in the mature stand it is 13 cm (5.1 in) thick, with the litter layer composing the upper third of it. In general, birch stands produce much more litter and therefore tend to have a thicker organic layer than do aspen stands.

2) Non-Woody Fuels in Black Spruce Stands: Broadleaf, moss and lichen litter types occur in black spruce stands, but not with the same frequency. Moss and moss litter occur in all pure spruce stands, though the amounts vary with the age of the stand. In young stands the green moss layer is less than 1 cm (.4 in) thick and the brown moss will average 5 cm (2 in) in thickness. During the 26-50-year period the green moss layer may be 7 cm (2.8 in) thick and the brown moss 8 cm (3.2 in) thick. With increasing age the green moss layer remains around 7 cm (2.8 in) thick, but the brown layer varies from 4-17 cm (1.6-6.7 in) in thickness.

Broadleaf litter occurs most extensively in the shrub stage (6-25-year period); at this time it averages 3 cm (1.2 in) in thickness. Its occurrence may be restricted to local patches beneath shrubs, etc.

Lichens can occur either intertwined with the moss or as extensive patches which excluded the moss. The depth of the former type is difficult to measure. The latter type can attain a depth of 2-6 cm (.8-2.4 in) in the 6-25-year-old stands. At this time the foliose lichens are extensive. The lichen layer seldom gets more than 6 cm (2.4 in) thick.

(3.8-4.2 in) thick in young stands (15-25-year-old), 4-6 cm thick in the tall shrub and dense hardwood stages (25-50-year and 50-80-year periods), and at least 4 cm (1.6 in) thick in mature stands (100-year-stands). In the young stands the organic layer is 2-5 cm (1.2-2 in) thick, and mostly composed of leaf litter. The organic layer gradually thickens as the stand age increases until in the mature stand it is 12 cm (5 in) thick, with the litter layer composing the upper third of it. In general, birch stands produce much more litter and therefore tend to have a thicker organic layer than do aspen stands.

2) Non-Woody Fuel in Black Spruce Stands: Grassleaf, moss and

lichen litter types occur in black spruce stands, but not with the same frequency. Moss and moss litter occur in all pure spruce stands, though the amounts vary with the age of the stand. In young stands the green moss layer is less than 2 cm (.8 in) thick and the brown moss will average 2 cm (.8 in) in thickness. During the 25-50-year period the green moss layer may be 3 cm (1.2 in) thick and the brown moss 5 cm (2 in) thick. With increasing age the green moss layer remains around 3 cm (1.2 in) thick, but the brown layer varies from 4-7 cm (1.6-2.8 in) in thickness. Grassleaf litter occurs most extensively in the shrub stage (10-25-year period); at this time it averages 2 cm (.8 in) in thickness. Its occurrence may be restricted to local patches beneath shrubs, etc. Lichens can occur either intertwined with the moss or as extensive patches which exclude the moss. The depth of the former type is difficult to measure. The latter type can attain a depth of 2-5 cm (.8-2 in) in the 5-25-year-old stands. At this time the former lichens are extensive. The lichen layer seldom gets more than 5 cm (2 in) thick.

Thickness of the organic layer, excluding the green moss layer, varies greatly. In recently burned stands patches of bare soil may occur beside Sphagnum mounds that are over 45 cm (18 in) high however, for the most part the organic layer averages range from 3-25 cm (1-10 in). This increases to 9-12 cm (3-5 in) in 6-25-year-old stands, 16-21 cm (6-8 in) in 26-50-year-old stands, and 16- >34 cm (6- >13 in) in 51-100-year-old stands. In mature stands, those >100-years old, it has a minimum average of 17 cm (7 in). The thinner organic layers occur on the drier black spruce sites, and thicker organic layers occur on the wetter black spruce sites. Mosses, especially Sphagnum, develop more rapidly on the more moist sites.

3) Non-Woody Fuels in White Spruce Stands: Mature white spruce stands have as much green moss and brown moss as the drier black spruce stands -- about 6-7 cm (2-3 in) of green moss and 7-9 cm (3-4 in) brown moss. However, white spruce stands have thinner total organic layers. These average 8-12 cm (3-5 in) in thickness, whereas in the black spruce type their minimum depth is 17 cm (7 in).

4) Non-Woody Fuels in Mixed Hardwood Spruce Stands: As might be expected in these mixed stands the amount of litter and organic material falls within the two extremes. The more hardwood present, the more leaf litter there will be, but usually the total will be less than occurs in the pure hardwood type. And, as predicted, the more spruce there is the more moss and lichen litter there will be and the deeper the organic layer will be.

Thickness of the organic layer, excluding the green moss layer, varies greatly, in recently burned stands patches of bare soil may occur beside *Sphagnum* mounds that are over 45 cm (18 in) high however, for the most part the organic layer averages from 3-25 cm (1-10 in). This increases to 9-15 cm (3-5 in) in 5-25-year-old stands, 15-25 cm (6-10 in) in 25-50-year-old stands, and 15-34 cm (6-13 in) in 51-100-year-old stands. In mature stands, those >100 years old, it has a minimum average of 17 cm (7 in). The thinnest organic layers occur on the white black spruce sites, and thicker organic layers occur on the white black spruce sites. However, especially *Sphagnum* develop more rapidly on the more moist sites.

3) Non-Woody Fuel in White Spruce Stands Mature white spruce stands have as much green moss and brown moss as the white black spruce stands -- about 6-7 cm (2-3 in) of green moss and 7-9 cm (3-4 in) brown moss. However, white spruce stands have thicker local organic layers. These average 8-15 cm (3-5 in) in thickness, whereas in the black spruce type their minimum depth is 17 cm (7 in).

4) Non-Woody Fuel in Mixed Hardwood-Stand As might be expected in these mixed stands the amount of litter and organic material falls within the two extremes. The more hardwood present, the more leaf litter there will be, but usually the total will be less than occurs in the pure hardwood type. And, as predicted, the more spruce there is the more moss and thicker litter there will be and the deeper the organic layer will be.

Summary of Forest Floor Fuels. -- Black spruce stands are generally quite flammable for the following reasons: 1) the volume of small slash ranges from 5-7 T/ha, 2) the thickness of the slash ranges from 0-5 dm, 3) the small diameter standing fuel begins within the slash layer, 1-3 dm above the ground for dead branches and 3-25 dm above the ground for living branches, and 4) The depth of the green moss ranges from 1-7 cm, the depth of the brown moss ranges from 2-17 cm, the depth of the lichen layer ranges from 0-6 cm and the total organic layer ranges from 3-34 cm. Leaf litter is not an important fuel type in black spruce stands.

Largest amounts of slash occur during the 6-25 year post-fire period when they will average over 10 T/ha. Eight T/ha occur during the 26-50-year period, 7 T/ha during the >100-year period, 6 T/ha during the 51-100-year period, and 5 T/ha during the 1-5-year period. Seventy-100% of the slash is composed of the more flammable small diameter slash.

In general, the older the stand the thicker the moss, moss litter, and organic layers. Lichen litter can attain what appear to be maximum depths (6 cm) as early as the 26-50 year period.

Mature white spruce stands are less flammable than mature black spruce stands because they 1) have less small slash than black spruce (6 T/ha for white spruce versus 7 T/ha for black spruce), 2) the slash layer is thinner (0-1 dm for white spruce and 0-4 dm for black spruce), 3) the small standing fuel begins higher above the ground (5-8 dm for white spruce and 3 dm for black spruce dead branches), and the organic layer is thinner (8-12 cm for white spruce and 17 cm for black spruce).

Summary of Forest Floor Features -- Black spruce stands are generally quite flammable for the following reasons: 1) the volume of small slash ranges from 5-7 t/ha, 2) the thickness of the slash ranges from 0-5 cm, 3) the small diameter standing fuel begins within the slash layer, 1-2 cm above the ground for dead branches and 3-25 cm above the ground for living branches, and 4) the depth of the green moss ranges from 1-3 cm, the depth of the brown moss ranges from 2-17 cm, the depth of the lichen layer ranges from 0-6 cm and the total organic layer ranges from 3-34 cm. Leaf litter is not an important fuel type in black spruce stands.

Largest amounts of slash occur during the 5-25 year post-fire period when they will average over 10 t/ha. Leaf litter occurs during the 25-50 year period, 7 t/ha during the >100 year period, 6 t/ha during the 51-100 year period, and 5 t/ha during the 1-5 year period. Seventy-100% of the slash is composed of the more flammable small diameter slash. In general, the older the stand the thicker the moss, more litter, and organic layers. Lichen litter can attain what appear to be maximum depths (6 cm) as early as the 25-50 year period.

Mature white spruce stands are less flammable than mature black spruce stands because they 1) have less small slash than black spruce (5 t/ha for white spruce versus 7 t/ha for black spruce), 2) the slash layer is thinner (0-1 cm for white spruce and 0-4 cm for black spruce), 3) the small standing fuel begins higher above the ground (5-8 cm for white spruce and 3 cm for black spruce dead branches), and the organic layer is thinner (0-12 cm for white spruce and 17 cm for black spruce).

On the other hand, the leaf litter layer is slightly thicker in the mature white spruce stand type (2 cm for white spruce and 0 for black spruce), and the living moss layers have comparable thickness in both stand types (6 in black spruce and 6-7 in white spruce). In addition the white spruce stands contain much more large slash (21 T/ha in white spruce and 1 T/ha in black spruce) however, this is due to the size of each log and not to the number of logs.

The hardwood stands are even less flammable for the following reasons:

1) the volume of small slash ranges between 1-5 T/ha or, if more, as in the 1-5-year post-fire period, the stand is protected by a dense layer of green sapling leaves which extend relatively close to the ground, 2) few dead branches remain on tree boles, and 3) the leaf litter is shallow, 2-3 cm thick, and moss and lichen layers do not exist. Fuels are not sufficiently abundant or continuous to carry a fire away from the point of origin.

F. Description of the Soils Found on Forested Upland

Slopes in Interior Alaska.

At the time this report was typed the interpretation of the soils data was still incomplete. When the interpretation is complete the information will be presented.

On the other hand, the leaf litter layer is slightly thicker in the mature white spruce stand type (2) or for white spruce and 0 for black spruce, and the living moss layers have comparable thickness in both stand types (6 in black spruce and 8-7 in white spruce). In addition the white spruce stands contain much more large slash (2) than in white spruce and 1 than in black spruce; however, this is due to the size of each log and not to the number of logs.

The hardwood stands are even less favorable for the following reasons:

- 1) The volume of small slash ranges between 1-2 t/ha or, if more, as in the 1-2-year post-fire period, the stand is protected by a dense layer of green sapling leaves which extend relatively close to the ground.
- 2) Few dead branches remain on tree boles, and 3) the leaf litter is shallow, 2-3 cm thick, and moss and lichen layers do not exist. Logs are not sufficiently abundant or continuous to carry a fire away from the point of origin.

F. Description of the Soils Found on Forested Upland

Soils in Interior Alaska

At the time this report was typed the interpretation of the soil data was still incomplete. When the interpretation is complete the information will be presented.

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APPENDIX A.

List of species identified from forested upland stands in interior Alaska, microtopography. Can. J. Bot. 46:1591-1599.

Code number	Scientific name	Common name used in paper
TREE SPECIES:		
903, 913, 921*	<i>Betula papyrifera</i> Marsh. var. <i>Kortii</i> (Ray) Fern. & Chap	Alaska paper birch, birch
906, 916, 926	<i>Larix laricina</i> (DuRoi) Koch	Tamarack
907, 917, 927	<i>Picea canadensis</i> (Mill.) B.S.P.	White spruce
908, 918, 928	<i>Picea mariana</i> (Mill.) B.S.P.	Black spruce
909, 919, 929	<i>Populus balsamifera</i> L.	Balsam poplar
910, 920, 930	<i>Populus tremuloides</i> Michx.	Quaking aspen, aspen
Total: 10		
SHRUB SPECIES:		
935	<i>Alder sp.</i> (A.L.) Koch	American green alder, green alder,
940	<i>Alder sp.</i> (A.L.) Koch	Thimble alder
945	<i>Betula glandulosa</i> Michx.	Bush birch
950	<i>Rosa sp.</i> (A.L.) Koch	Prickly rose, rose
955	<i>Rubus sp.</i> (A.L.) Koch	American red raspberry, raspberry
960	<i>Salix alba</i> (L.) Mill.	White willow
965	<i>Salix arbuscula</i> Michx.	Littleleaf willow
970	<i>Salix bebbiana</i> Berg.	Bush willow
975	<i>Salix glauca</i> L.	Grayleaf willow
980	<i>Salix glauca</i> L. subsp. <i>fulva</i> (Chen.) Aron	Grayleaf willow

* 90 = type; 91 = duplicate; 92 = specimen.

* Underlined numbers: those used in the classification and ordination analysis.

Microbiology, Can. J. Bot. 40: 1231-1234, 1962.

APPENDIX A.

List of species identified from forested upland stands in interior Alaska.

<u>Code number</u>	<u>Scientific name</u>	<u>Common name used in paper</u>
TREE SPECIES:		
<u>903</u> , <u>913</u> , <u>923</u> ^{**}	<u>Betula papyrifera</u> Marsh. var. <u>humilis</u> (Reg.) Fern. & Raup	Alaska paper birch, birch
<u>906</u> , <u>916</u> , <u>926</u>	<u>Larix laricina</u> (DuRoi) K. Koch	Tamarack
<u>902</u> , <u>912</u> , <u>922</u>	<u>Picea glauca</u> (Moench) Voss	White spruce
<u>901</u> , <u>911</u> , <u>921</u>	<u>Picea mariana</u> (Mill.) B.S.P.	Black spruce
<u>905</u> , <u>915</u> , <u>925</u>	<u>Populus balsamifera</u> L.	Balsam poplar
<u>904</u> , <u>914</u> , <u>924</u>	<u>Populus tremuloides</u> Michx.	Quaking aspen, aspen
Total: 18		
TALL SHRUB SPECIES:		
<u>025</u>	<u>Alnus crispa</u> (Ait.) Pursh	American green alder, green alder
<u>048</u>	<u>Alnus tenuifolia</u> Nutt.	Thinleaf alder
<u>027</u>	<u>Betula glandulosa</u> Michx.	Resin birch
<u>024</u>	<u>Rosa acicularis</u> Lindl.	Prickly rose, rose
<u>047</u>	<u>Rubus idaeus</u> L. var. <u>strigosus</u> (Michx.) Maxim.	American red raspberry, raspberry
<u>031</u>	<u>Salix alaxensis</u> (Anderss.) Cov.	Feltleaf willow
<u>032</u>	<u>Salix arbusculoides</u> Anderss.	Littletree willow
<u>030</u>	<u>Salix bebbiana</u> Sarg.	Bebb willow
<u>034</u>	<u>Salix glauca</u> L.	Grayleaf willow
<u>033</u>	<u>Salix planifolia</u> Pursh. subsp. <u>pulchra</u> (Cham.) Argus	Diamondleaf willow

* 90_ = trees; 91_ = saplings; 92_ = seedlings.

** Underscored numbers: those used in the classification and ordination analysis.

Appendix A

List of species identified from forested island stands in interior

Alaska

Code number	Scientific name	Common name used in paper
TREE SPECIES:		
903, 913, 914	<i>Betula glandulosa</i> Michx.	Alaska paper birch
903, 913, 914	<i>Betula glandulosa</i> Michx. var. <i>humboldtii</i> (Reich.) Fern. & Raup	birch
904, 913, 914	<i>Larix laricina</i> (DuRoi) Koch	Tamarack
903, 913, 914	<i>Picea canadensis</i> (Mill.) B.S.P.	White spruce
901, 911, 921	<i>Picea mariana</i> (Mill.) B.S.P.	Black spruce
902, 912, 922	<i>Populus balsamifera</i> L.	Balsam poplar
901, 911, 921	<i>Populus tremuloides</i> Michx.	Quaking aspen, aspen
Total: 18		
TALL SHRUB SPECIES:		
925	<i>Alnus crispa</i> (Ait.) Pursh	American green alder, green alder
926	<i>Alnus tenuifolia</i> Nutt.	Thicket alder
927	<i>Betula glandulosa</i> Michx.	Betula birch
928	<i>Rosa acicularis</i> (L.)	Blackberry rose, rose
941	<i>Rubus idaeus</i> L. var. <i>strigosus</i> (Michx.) Reiche	American red raspberry, raspberry
930	<i>Salix glauca</i> (Anders.) Link.	Goose willow
931	<i>Salix arbuscula</i> Anders.	Littleleaf willow
932	<i>Salix repens</i> L.	Bobo willow
933	<i>Salix glauca</i> L.	Grayish willow
934	<i>Salix glauca</i> L. var. <i>arbuscula</i> (Anders.) Link.	Diamondleaf willow

* 90 = forest; 91 = scrubland; 92 = meadow

** Underlined numbers: those used in the classification and ordination analysis

Code numberScientific nameCommon name used
in paper

TALL SHRUB SPECIES, cont.

<u>029</u>	<u>Salix scouleriana</u> Barrat.	Scouler willow
<u>028</u>	<u>Salix</u> species	Unidentified tall shrub willow
<u>041</u>	<u>Viburnum edule</u> (Michx.) Raf.	Highbush cranberry

Total: 12

LOW SHRUB SPECIES

<u>252</u>	<u>Andromeda polifolia</u> L.	Bog-rosemary
<u>255</u>	<u>Arctostaphylos rubra</u> (Rehd. & Wilson) Fern.	Red-fruit bearberry
<u>256</u>	<u>Arctostaphylos uva-ursi</u> (L.) Spreng.	Bearberry
<u>251</u>	<u>Betula nana</u> L.	Dwarf arctic birch
<u>222</u>	<u>Chamaedaphne calyculata</u> (L.) Moench.	Leatherleaf
<u>276</u>	<u>Dryas integrifolia</u> Vahl.	Entire-leaf mountain-avens
<u>218</u>	<u>Empetrum nigrum</u> L.	Crowberry
<u>241</u>	<u>Ledum decumbens</u> (Ait.) Small	Narrow-leaf Labrador-tea
<u>242</u>	<u>Ledum groenlandicum</u> Oeder	Labrador-tea
<u>221</u>	<u>Linnaea borealis</u> L.	Twin-flower
<u>266</u>	<u>Loiseleuria procumbens</u> (L.) Des.	Alpine-azalea
<u>257</u>	<u>Potentilla fruticosa</u> L.	Bush cinquefoil
<u>247</u>	<u>Ribes triste</u> Pall.	American red currant
<u>202</u>	<u>Salix myrtillofolia</u> Anderss.	Low blueberry willow
<u>228</u>	<u>Salix</u> species	Unidentified low shrub willow

TALL SHRUB SPECIES, cont.

Scoutlet willow	<i>Salix scouletiana</i> Barker	032
Unidentified tall shrub willow	<i>Salix</i> species	038
Highway shrubbery	<i>Viburnum edule</i> (Mill.) Raf.	041
Total: 12		
LOW SHRUB SPECIES		
Bog shrubbery	<i>Androsace polifolia</i> L.	252
Bog shrub shrubbery	<i>Arctostaphylos uva-ursi</i> (L.) A. Nelson-Park	253
Bog shrub	<i>Arctostaphylos uva-ursi</i> (L.) Curtis	254
Forest arctic shrub	<i>Betula nana</i> L.	251
Forest shrubbery	<i>Chamaenerion caeruleum</i> (L.) Moench	252
Forest shrub shrubbery	<i>Grayia integrifolia</i> Vahl	253
Shrubbery	<i>Juniperus communis</i> L.	254
Forest shrub shrubbery	<i>Ledum decumbens</i> (L.) Smith	251
Forest shrub	<i>Ledum nigrum</i> L.	252
Forest shrub	<i>Ledum palustre</i> L.	253
Forest shrub	<i>Ledum palustre</i> L.	254
Forest shrub	<i>Ledum palustre</i> L.	255
Forest shrub	<i>Ledum palustre</i> L.	256
Forest shrub	<i>Ledum palustre</i> L.	257
Forest shrub	<i>Ledum palustre</i> L.	258
Forest shrub	<i>Ledum palustre</i> L.	259
Forest shrub	<i>Ledum palustre</i> L.	260
Forest shrub	<i>Ledum palustre</i> L.	261
Forest shrub	<i>Ledum palustre</i> L.	262
Forest shrub	<i>Ledum palustre</i> L.	263
Forest shrub	<i>Ledum palustre</i> L.	264
Forest shrub	<i>Ledum palustre</i> L.	265
Forest shrub	<i>Ledum palustre</i> L.	266
Forest shrub	<i>Ledum palustre</i> L.	267
Forest shrub	<i>Ledum palustre</i> L.	268
Forest shrub	<i>Ledum palustre</i> L.	269
Forest shrub	<i>Ledum palustre</i> L.	270
Forest shrub	<i>Ledum palustre</i> L.	271
Forest shrub	<i>Ledum palustre</i> L.	272
Forest shrub	<i>Ledum palustre</i> L.	273
Forest shrub	<i>Ledum palustre</i> L.	274
Forest shrub	<i>Ledum palustre</i> L.	275
Forest shrub	<i>Ledum palustre</i> L.	276
Forest shrub	<i>Ledum palustre</i> L.	277
Forest shrub	<i>Ledum palustre</i> L.	278
Forest shrub	<i>Ledum palustre</i> L.	279
Forest shrub	<i>Ledum palustre</i> L.	280
Forest shrub	<i>Ledum palustre</i> L.	281
Forest shrub	<i>Ledum palustre</i> L.	282
Forest shrub	<i>Ledum palustre</i> L.	283
Forest shrub	<i>Ledum palustre</i> L.	284
Forest shrub	<i>Ledum palustre</i> L.	285
Forest shrub	<i>Ledum palustre</i> L.	286
Forest shrub	<i>Ledum palustre</i> L.	287
Forest shrub	<i>Ledum palustre</i> L.	288
Forest shrub	<i>Ledum palustre</i> L.	289
Forest shrub	<i>Ledum palustre</i> L.	290
Forest shrub	<i>Ledum palustre</i> L.	291
Forest shrub	<i>Ledum palustre</i> L.	292
Forest shrub	<i>Ledum palustre</i> L.	293
Forest shrub	<i>Ledum palustre</i> L.	294
Forest shrub	<i>Ledum palustre</i> L.	295
Forest shrub	<i>Ledum palustre</i> L.	296
Forest shrub	<i>Ledum palustre</i> L.	297
Forest shrub	<i>Ledum palustre</i> L.	298
Forest shrub	<i>Ledum palustre</i> L.	299
Forest shrub	<i>Ledum palustre</i> L.	300
Forest shrub	<i>Ledum palustre</i> L.	301
Forest shrub	<i>Ledum palustre</i> L.	302
Forest shrub	<i>Ledum palustre</i> L.	303
Forest shrub	<i>Ledum palustre</i> L.	304
Forest shrub	<i>Ledum palustre</i> L.	305
Forest shrub	<i>Ledum palustre</i> L.	306
Forest shrub	<i>Ledum palustre</i> L.	307
Forest shrub	<i>Ledum palustre</i> L.	308
Forest shrub	<i>Ledum palustre</i> L.	309
Forest shrub	<i>Ledum palustre</i> L.	310
Forest shrub	<i>Ledum palustre</i> L.	311
Forest shrub	<i>Ledum palustre</i> L.	312
Forest shrub	<i>Ledum palustre</i> L.	313
Forest shrub	<i>Ledum palustre</i> L.	314
Forest shrub	<i>Ledum palustre</i> L.	315
Forest shrub	<i>Ledum palustre</i> L.	316
Forest shrub	<i>Ledum palustre</i> L.	317
Forest shrub	<i>Ledum palustre</i> L.	318
Forest shrub	<i>Ledum palustre</i> L.	319
Forest shrub	<i>Ledum palustre</i> L.	320
Forest shrub	<i>Ledum palustre</i> L.	321
Forest shrub	<i>Ledum palustre</i> L.	322
Forest shrub	<i>Ledum palustre</i> L.	323
Forest shrub	<i>Ledum palustre</i> L.	324
Forest shrub	<i>Ledum palustre</i> L.	325
Forest shrub	<i>Ledum palustre</i> L.	326
Forest shrub	<i>Ledum palustre</i> L.	327
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Forest shrub	<i>Ledum palustre</i> L.	329
Forest shrub	<i>Ledum palustre</i> L.	330
Forest shrub	<i>Ledum palustre</i> L.	331
Forest shrub	<i>Ledum palustre</i> L.	332
Forest shrub	<i>Ledum palustre</i> L.	333
Forest shrub	<i>Ledum palustre</i> L.	334
Forest shrub	<i>Ledum palustre</i> L.	335
Forest shrub	<i>Ledum palustre</i> L.	336
Forest shrub	<i>Ledum palustre</i> L.	337
Forest shrub	<i>Ledum palustre</i> L.	338
Forest shrub	<i>Ledum palustre</i> L.	339
Forest shrub	<i>Ledum palustre</i> L.	340
Forest shrub	<i>Ledum palustre</i> L.	341
Forest shrub	<i>Ledum palustre</i> L.	342
Forest shrub	<i>Ledum palustre</i> L.	343
Forest shrub	<i>Ledum palustre</i> L.	344
Forest shrub	<i>Ledum palustre</i> L.	345
Forest shrub	<i>Ledum palustre</i> L.	346
Forest shrub	<i>Ledum palustre</i> L.	347
Forest shrub	<i>Ledum palustre</i> L.	348
Forest shrub	<i>Ledum palustre</i> L.	349
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Forest shrub	<i>Ledum palustre</i> L.	352
Forest shrub	<i>Ledum palustre</i> L.	353
Forest shrub	<i>Ledum palustre</i> L.	354
Forest shrub	<i>Ledum palustre</i> L.	355
Forest shrub	<i>Ledum palustre</i> L.	356
Forest shrub	<i>Ledum palustre</i> L.	357
Forest shrub	<i>Ledum palustre</i> L.	358
Forest shrub	<i>Ledum palustre</i> L.	359
Forest shrub	<i>Ledum palustre</i> L.	360
Forest shrub	<i>Ledum palustre</i> L.	361
Forest shrub	<i>Ledum palustre</i> L.	362
Forest shrub	<i>Ledum palustre</i> L.	363
Forest shrub	<i>Ledum palustre</i> L.	364
Forest shrub	<i>Ledum palustre</i> L.	365
Forest shrub	<i>Ledum palustre</i> L.	366
Forest shrub	<i>Ledum palustre</i> L.	367
Forest shrub	<i>Ledum palustre</i> L.	368
Forest shrub	<i>Ledum palustre</i> L.	369
Forest shrub	<i>Ledum palustre</i> L.	370
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Forest shrub	<i>Ledum palustre</i> L.	374
Forest shrub	<i>Ledum palustre</i> L.	375
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Forest shrub	<i>Ledum palustre</i> L.	377
Forest shrub	<i>Ledum palustre</i> L.	378
Forest shrub	<i>Ledum palustre</i> L.	379
Forest shrub	<i>Ledum palustre</i> L.	380
Forest shrub	<i>Ledum palustre</i> L.	381
Forest shrub	<i>Ledum palustre</i> L.	382
Forest shrub	<i>Ledum palustre</i> L.	383
Forest shrub	<i>Ledum palustre</i> L.	384
Forest shrub	<i>Ledum palustre</i> L.	385
Forest shrub	<i>Ledum palustre</i> L.	386
Forest shrub	<i>Ledum palustre</i> L.	387
Forest shrub	<i>Ledum palustre</i> L.	388
Forest shrub	<i>Ledum palustre</i> L.	389
Forest shrub	<i>Ledum palustre</i> L.	390
Forest shrub	<i>Ledum palustre</i> L.	391
Forest shrub	<i>Ledum palustre</i> L.	392
Forest shrub	<i>Ledum palustre</i> L.	393
Forest shrub	<i>Ledum palustre</i> L.	394
Forest shrub	<i>Ledum palustre</i> L.	395
Forest shrub	<i>Ledum palustre</i> L.	396
Forest shrub	<i>Ledum palustre</i> L.	397
Forest shrub	<i>Ledum palustre</i> L.	398
Forest shrub	<i>Ledum palustre</i> L.	399
Forest shrub	<i>Ledum palustre</i> L.	400

<u>Code number</u>	<u>Scientific name</u>	<u>Common name used in paper</u>
LOW SHRUB SPECIES, cont.		
220	<u>Shepherdia canadensis</u> (L.) Nutt.	Buffaloberry
217	<u>Spirea beauverdiana</u> Schneid.	Beauverd spirea, spirea
212	<u>Vaccinium oxycoccus</u> L.	Bog cranberry
215	<u>Vaccinium vitis-idaea</u> L.	Mountain-cranberry
214	<u>Vaccinium uliginosum</u> L.	Bog blueberry
Total: 20		
HERB SPECIES		
346	<u>Achillea</u> species	Unidentified yarrow
329	<u>Aconitum delphinifolium</u> DC.	Monkshood
408	<u>Actaea rubra</u> (Ait.) Wild. subsp. <u>rubra</u>	Baneberry
326	<u>Adoxa moschatellina</u> L.	Moschatel
455	<u>Agrostis scabra</u> Willd.	Ticklegrass
361	<u>Anemone richardsonii</u> Hook.	Yellow anemone
311	<u>Arctagrostis</u> species	Unidentified poker- grass
445	<u>Astragalus</u> species	Unidentified milk vetch
402	<u>Boschniakia rossica</u> (Cham. & Schlecht.) Fedtsch.	Ground-cone, poque
454	<u>Calamagrostis canadensis</u> (Michx.) Beauv.	Bluejoint
312	<u>Calamagrostis</u> species	Unidentified bluejoint- reedgrass
341	<u>Calypso bulbosa</u> (L.) Rchb. f.	Calypso orchid
439	<u>Carex concinna</u> R. Br.	Low northern sedge

Common name used
in paper

Scientific name

Code number

LOW SHRUB SPECIES, cont.

320	<i>Stemmatia canadensis</i> (L.) Hook.	Wetlands
317	<i>Salix humilis</i> Michx.	Wetlands
316	<i>Vaccinium oxycoccos</i> L.	Wetlands
315	<i>Vaccinium vitis-idaea</i> L.	Wetlands
314	<i>Vaccinium uliginosum</i> L.	Wetlands

Total: 54

HERB SPECIES

346	<i>Achillea millefolium</i> DC.	Wetlands
359	<i>Asplenium adnigrum</i> DC.	Wetlands
404	<i>Asplenium platyneuron</i> (L.) Willd. subsp. <i>viride</i>	Wetlands
378	<i>Asplenium platyneuron</i> L.	Wetlands
485	<i>Aster multiflorus</i> Willd.	Wetlands
361	<i>Asplenium platyneuron</i> Hook.	Wetlands
377	<i>Aster multiflorus</i> Willd.	Wetlands
412	<i>Aster multiflorus</i> Willd.	Wetlands
403	<i>Asplenium platyneuron</i> (L.) Willd. subsp. <i>viride</i>	Wetlands
454	<i>Asplenium platyneuron</i> (L.) Willd. subsp. <i>viride</i>	Wetlands
375	<i>Asplenium platyneuron</i> Willd.	Wetlands
341	<i>Asplenium platyneuron</i> (L.) Willd. subsp. <i>viride</i>	Wetlands
430	<i>Asplenium platyneuron</i> L.	Wetlands

<u>Code number</u>	<u>Scientific name</u>	<u>Common name used in paper</u>
HERB SPECIES, cont.		
314	<u>Carex</u> species	Unidentified sedge
359	<u>Castilleja</u> species	Unidentified paintbrush
456	<u>Cerastium</u> species	Unidentified chickweed
453	<u>Chenopodium capitatum</u> (L.) Aschers.	Strawberry blite
442	<u>Cnidium cnidifolium</u> (Turcx.) Schischk.	No common name
309	<u>Cornus canadensis</u> L.	Bunchberry, dwarf dogwood
353	<u>Corydalis sempervirens</u> (L.) Pers.	Pale corydalis
348	<u>Crepis nana</u> Richards.	Dwarf hawk's beard
331	<u>Delphinium glaucum</u> S. Wats.	Glaucous larkspur
350	<u>Drosera rotundifolia</u> L.	Round-leaf sundew
308	<u>Epilobium angustifolium</u> L.	Fireweed
395	<u>Epilobium</u> species	Unidentified willow-herb
324	<u>Equisetum arvense</u> L.	Meadow horsetail
330	<u>Equisetum pratense</u> Ehrh.	Meadow horsetail
319	<u>Equisetum scirpoides</u> Michx.	Dwarf scouring-rush
303	<u>Equisetum silvaticum</u> L.	Woodland horsetail
396	<u>Erigeron</u> species	No common name
315	<u>Eriophorum</u> species	Unidentified cottongrass
320	<u>Eriophorum vaginatum</u> L.	Cottongrass, tussock
327	<u>Galium boreale</u> L.	Northern bedstraw
394	<u>Galium</u> species	Unidentified bedstraw
360	<u>Gentiana glauca</u> Pall.	Glaucous gentian
415	<u>Gentiana propinqua</u> Richards.	No common name

HERB SPECIES, cont.	Colo number	Scientific name	Common name used in 1957
314		<i>Carex species</i>	Unidentified sedge
354		<i>Castilleja species</i>	Unidentified paintbrush
458		<i>Cerastium species</i>	Unidentified chickweed
453		<i>Chenopodium capitatum</i> (L.) Moench	Stinkweed
445		<i>Chilopsis cordifolia</i> (Tuck.) Schisch	No common name
509		<i>Corylus canadensis</i> L.	Bunchberry, dwarf honey
523		<i>Corydalis sempervirens</i> (L.) Pers.	Pale corydalis
548		<i>Cypripedium acaule</i> Michx.	White lady's slipper
571		<i>Delphinium glaucum</i> S. Wats.	Bluebonnet
580		<i>Dracopis rotundifolia</i> L.	Round-leaf sundew
588		<i>Echinops angustifolius</i> L.	Fireweed
592		<i>Echinops species</i>	Unidentified willow-herb
594		<i>Eupatorium species</i> L.	Meadow horsetail
598		<i>Eupatorium purpureum</i> Ehrh.	Meadow horsetail
599		<i>Eupatorium scirpoides</i> Michx.	Heart scouring-rush
603		<i>Eupatorium strigosum</i> L.	Woodland horsetail
595		<i>Eriogonum species</i>	No common name
596		<i>Eriogonum species</i>	Unidentified cottongrass
597		<i>Eriogonum vaginatum</i> L.	Cottongrass, twined
598		<i>Galium boreale</i> L.	Northern bedstraw
599		<i>Galium species</i>	Unidentified bedstraw
599		<i>Galium glauca</i> Pall.	Bluish-green
600		<i>Galium gracilentum</i> Moench	No common name

<u>Code number</u>	<u>Scientific name</u>	<u>Common name used in paper</u>
HERB SPECIES, cont.		
304	<u>Geocaulon lividum</u> (Richards.) Fern.	No common name
334	<u>Goodyera repens</u> (L.) R. Br. var. <u>ophioides</u> Fern.	Rattlesnake plantain
321	<u>Gramineae</u> species	Unidentified grass
342	<u>Gymnocarpium dryopteris</u> (L.) Newm.	Oak-fern
446	<u>Hedysarum</u> species	Unidentified sweet-vetch
316	Herbaceous unknown	Unidentified herb
338	<u>Iris setosa</u> Pall. subsp. <u>interior</u> (Anders.) Hult.	Wild iris
344	<u>Juncus</u> species	Unidentified rush
352	<u>Lupinus arcticus</u> S. Wats.	Alpine lupine
440	<u>Luzula</u> species	Unidentified woodrush
403	<u>Lycopodium annotinum</u> L.	Stiff club moss
404	<u>Lycopodium complanatum</u> L.	Christmas green, ground cedar
405	<u>Lycopodium clavatum</u> L. subsp. <u>monostachyon</u> (Grev. & Hook.) Sel.	Running clubmoss
310	<u>Mertensia paniculata</u> (Ait.) G. Don	Tall bluebell
325	<u>Moehringia lateriflora</u> (L.) Frenz1	Grove sandwort, blunt- leaved sandwort
397	<u>Parnassia palustris</u> L. subsp. <u>neogaea</u> (Fern.) Hult.	Northern grass-of- Parnassus
337	<u>Pedicularis labradorica</u> Wirsing	Labrador lousewort
391	<u>Petasites frigidus</u> (L.) Franch.	Arctic sweet coltsfoot
351	<u>Pinguicula villosa</u> L.	Hairy butterwort
409	<u>Platanthera</u> species	Unidentified bog orchid
313	<u>Poa</u> species	Unidentified bluegrass

HERB SPECIES, cont.

302	<i>Geocaulon lividum</i> (Richard.) Torr.	No common name
322	<i>Geophila repens</i> (L.) R. Br. var. <i>geophila</i> Torr.	Raffinose plantain
321	<i>Gramineae</i> species	Unidentified grass
342	<i>Gymnocarpium dryopteris</i> (L.) New.	Dak-tan
446	<i>Podocarpus</i> species	Unidentified sweet-satch
316	<i>Podocarpus</i> unknown	Unidentified herb
338	<i>Lyth. salicaria</i> Poir. subsp. <i>infertior</i> (Anders.) Nutt.	Mild iris
341	<i>Thalictrum</i> species	Unidentified rush
442	<i>Lactuca arvensis</i> L. var.	Asian lettuce
440	<i>Lupinus</i> species	Unidentified woodpecker
402	<i>Lycopodium annotinum</i> L.	Stiff club moss
404	<i>Lycopodium complanatum</i> L.	Christmas fern, ground cedar
402	<i>Lycopodium obscurum</i> L. subsp. <i>complanatum</i> (L.) A. Hook. Sel.	Running clubmoss
310	<i>Mertensia paniculata</i> (Ait.) B. Don	Tall bluebell
322	<i>Metastachya latifolia</i> (L.) Presl	Grass seedhead, blunt- leaved seedhead
391	<i>Parthenocissus vitacea</i> L. subsp. <i>parthenocissus</i> (L.) Nutt.	Wormwood grass- vine
332	<i>Pedicularis latifolia</i> Wiering	Lavender "lousewort"
391	<i>Peltandra virginica</i> (L.) Franck.	Arctic sweet coltsfoot
321	<i>Pinguicula vulgaris</i> L.	Mealy butterwort
408	<i>Pistillaria</i> species	Unidentified dog orchid
312	<i>Poa</i> species	Unidentified bluegrass

<u>Code number</u>	<u>Scientific name</u>	<u>Common name used in paper</u>
HERB SPECIES, cont.		
345	<u>Polemonium acutiflorum</u> Willd.	Jacob's ladder
305	<u>Polygonum alaskanum</u> (Small) Wight	Alaska wild rhubarb
322	<u>Polygonum bistorta</u> L. subsp. <u>plumusum</u> (Small) Hult.	Meadow bistort
349	<u>Potentilla</u> species	Unidentified cinquefoil
328	<u>Pyrola asarifolia</u> Michx.	Liverleaf wintergreen
335	<u>Pyrola chlorantha</u> Sw.	No common name
336	<u>Pyrola grandiflora</u> Radius	Large-flower winter- green
307	<u>Pyrola secunda</u> L.	One-sided wintergreen
355	<u>Pyrola</u> species	Unidentified wintergreen
358	<u>Ranunculus</u> species	Unidentified buttercup
339	<u>Rubus arcticus</u> L.	Nagoonberry
301	<u>Rubus chamaemorus</u> L.	Cloudberry
323	<u>Rumex arcticus</u> Trautv.	Arctic dock
383	<u>Saussurea angustifolia</u> (Willd.) DC	No common name
427	<u>Saxifraga punctata</u> L.	Brook saxifrage
444	<u>Senecio</u> species	Unidentified groundsel
443	<u>Silene repens</u> Patrin	Pink campion
357	<u>Solidago</u> species	Unidentified goldenrod
302	<u>Stellaria</u> species	Unidentified starwort
374	<u>Trientalis eurupaea</u> L.	Broad-leaf starflower
384	<u>Valeriana capitata</u> Pall.	Capitate valerian
333	<u>Viola biflora</u> L.	Two-flower violet
438	<u>Zygadenus elegans</u> Pursh	White camass

Total: 80

Common name given
in paper

Scientific name

Code number

HERB SPECIES, cont.

345	<i>Polypodium scolopendria</i> Willd.	Jacob's ladder
346	<i>Polypodium alaskanum</i> (Sm.) Wint.	Alaska polypodium
347	<i>Polypodium virginicum</i> L. subsp. <i>virginicum</i> (Sm.) Nutt.	Meadow polypodium
348	<i>Potentilla</i> species	Unidentified cineraria
349	<i>Potentilla anserina</i> Michx.	1-year plant wintergreen
350	<i>Potentilla canadensis</i> Sw.	No common name
351	<i>Potentilla grandiflora</i> Michx.	Large-flower wintergreen
352	<i>Potentilla</i> species	One-sided wintergreen
353	<i>Potentilla</i> species	Unidentified wintergreen
354	<i>Potentilla</i> species	Unidentified buttercup
355	<i>Rubus strigosus</i> L.	Rubusberry
356	<i>Rubus chrysanthus</i> L.	Rubusberry
357	<i>Rubus arcticus</i> Treutl.	Arctic dock
358	<i>Saxifraga angustifolia</i> (Willd.) DC	No common name
359	<i>Saxifraga</i> spicata L.	Wood saxifrage
360	<i>Saxifraga</i> species	Unidentified groundsel
361	<i>Silene vulgaris</i> Pers.	Pink campion
362	<i>Silene</i> species	Unidentified goldenrod
363	<i>Silene</i> species	Unidentified starwort
364	<i>Trifolium europaeum</i> L.	Broad-leaf starflower
365	<i>Valeriana capitata</i> Pall.	Capitate valerian
366	<i>Viola officinalis</i> L.	Two-lobed violet
367	<i>Viola</i> species	White pansy

<u>Code number</u>	<u>Scientific name</u>	<u>Common name used in paper</u>
MOSS SPECIES		
126	<u>Aulacomnium palustre</u> (Hedw.) Schwaegr.	No common name
130	<u>Aulacomnium turgidum</u> (Wahlenb.) Schwaegr.	No common name
139	<u>Brachythecium salebrosum</u> B.S.G.	No common name
138	<u>Campylium</u> species	No common name
133	<u>Ceratodon purpureus</u> (Hedw.) Brid.	No common name
129	<u>Dicranum</u> species	No common name
128	<u>Drepanocladus uncinatus</u> (Hedw.) Wernst.	No common name
140	<u>Eurhynchium</u> species	No common name
122	<u>Hylocomium splendens</u> (Hedw.) B.S.G.	Feathermoss
137	<u>Hypnum</u> species	No common name
121	Leafy liverwort species	
131	<u>Marchantia polymorpha</u> L.	No common name
132	<u>Mnium</u> species	No common name
120	Moss, unknown	No common name
123	<u>Pleurozium schreberi</u> (Brid.) Mitt.	Feathermoss
124	<u>Polytrichum</u> species	No common name
125	<u>Ptilium crista-castrensis</u> (Hedw.) De Not.	Feathermoss
136	<u>Rhytidia delphus</u> species	No common name
127	<u>Sphagnum</u> species	No common name

Total: 19

Common name used
in paper

Scientific name

Code number

WGS SPECIES

No common name	<i>Aulacomnium palustre</i> (Hedw.) Schwartz	129
No common name	<i>Aulacomnium turgidum</i> (Hedw.) Schwartz	130
No common name	<i>Brachythecium sphaerocarpum</i> B.S.P.	131
No common name	<i>Cephaezoma species</i>	132
No common name	<i>Ceratodon purpureus</i> (Hedw.) Brid.	133
No common name	<i>Liverwort species</i>	134
No common name	<i>Plagiodontium lachrymans</i> (Hedw.) Hedw.	135
No common name	<i>Plagiodontium species</i>	136
Feathermoss	<i>Plagiodontium sphenolobos</i> (Hedw.) B.S.P.	137
No common name	<i>Hynum species</i>	138
No common name	<i>Leafy liverwort species</i>	139
No common name	<i>Plagiodontium polytrichum</i> L.	140
No common name	<i>Plagiodontium species</i>	141
No common name	<i>Plagiodontium species</i>	142
No common name	<i>Plagiodontium species</i>	143
Feathermoss	<i>Plagiodontium schreberei</i> (Hedw.) Brid.	144
No common name	<i>Plagiodontium species</i>	145
Feathermoss	<i>Plagiodontium cristatella</i> (Hedw.) B.S.P.	146
No common name	<i>Plagiodontium species</i>	147
No common name	<i>Plagiodontium species</i>	148

Total: 19

<u>Code number</u>	<u>Scientific name</u>	<u>Common name used in paper</u>
LICHEN SPECIES		
104	<u>Alectoria</u> species	No common name
090	<u>Cetraria</u> <u>cucullata</u> (Bell.) Ach.	No common name
091	<u>Cetraria</u> <u>islandica</u> (L.) Ach.	No common name
093	<u>Cetraria</u> <u>pinastri</u> (Scop.) S. Gray	No common name
113	<u>Cetraria</u> <u>richardsonii</u> Hook.	No common name
098	<u>Cladina</u> <u>arbuscula</u> (Wallr.) Hale & W. Culb. (= <u>Cladonia</u> <u>sylvatica</u> (L.) Hoffm.)	Reindeer lichen
097	<u>Cladina</u> <u>rangiferina</u> (L.) Harm. (= <u>Cladonia</u> <u>rangiferina</u> (L.) Web.)	Reindeer lichen
095	<u>Cladonia</u> <u>amaurocraea</u> (Flörke) Schaer.	No common name
096	<u>Cladonia</u> <u>gracilis</u> (L.) Willd.	No common name
094	<u>Cladonia</u> <u>stellaris</u> (Opiz) Pouz. & Vezda (= <u>Cladonia</u> <u>alpestris</u> (L.) Rabenh.)	No common name
099	<u>Cladonia</u> species	No common name
087	Crustose species	
089	Foliose species	
088	Fruticose species	
101	<u>Nephroma</u> <u>arcticum</u> (L.) Torss.	No common name
102	<u>Parmelia</u> species	No common name
106	<u>Peltigera</u> <u>aphthosa</u> (L.) Willd.	No common name
107	<u>Peltigera</u> <u>canina</u> (L.) Willd.	No common name
108	<u>Peltigera</u> species	No common name
105	<u>Stereocaulon</u> species	No common name
103	<u>Usnea</u> species	No common name

Total: 21

Total plant species: 170

APPENDIX B.

List of important equations used in the computer summary programs
HERBSUM, SHRUSUM, SEEDSUM, and TREESUM.

HERBSUM Summary Program. --

1) Average Percent Cover: $C_{(A)} = C_{(T)}/P_{(S)}$

Where $C_{(A)}$ = average percent cover of species i , $C_{(T)}$ = total cover of species i and $P_{(S)}$ = total number of plots where species i occurred.

2) Percent Frequency of Occurrence: $F = P_{(S)}/P_{(T)}$

Where F = percent frequency, $P_{(S)}$ = total number of plots where species i occurred, and $P_{(T)}$ = total number of plots or 20.

SHRUSUM Summary Program. --

3) Total Basal Area: $B_{(T)} = \Sigma(n\pi r^2)$

Where $B_{(T)}$ = total basal area, Σ = sum of all size classes, n = number of stems in size class i , π = the constant, 3.14, and $r^2 = (\text{size class} - .5/2)^2$.

4) Percent Frequency of Occurrence: (See equation 2).

5) Density/ha: $D = (N/P)10,000$

Where D = density per hectare, N = total number of shrub stems for species i , P = total plot size or $20(4m^2) = 80m^2$, and 10,000 is the number of m^2 in a hectare.

6) Basal Area/ha: $B_{(A)} = (B_{(T)}/P)D$

Where $B_{(A)}$ = basal area per hectare, $B_{(T)}$ = total basal area, P = total plot size or $20(4m^2) = 80m^2$, and D = density per hectare.

APPENDIX B

List of important equations used in the computer summary program

HERBIVORE, SHRUBS, SEEDS, and TREES

HERBIVORE SUMMARY PROGRAM

- 1) Average Percent Cover:
$$\bar{C}(A) = \frac{\sum C_i(T)}{T} \quad (A)$$

Where $\bar{C}(A)$ = average percent cover of species A ; $C_i(T)$ = total cover of species A in plot T where species A occurred.
- 2) Percent Frequency of Occurrence:
$$F = \frac{P}{T} \quad (T)$$

Where F = percent frequency, P = total number of plots where species A occurred, and T = total number of plots or 50.

SHRUB SUMMARY PROGRAM

- 3) Total basal area:
$$B(T) = \sum b_i^2 \quad (T)$$

Where $B(T)$ = total basal area, b_i = sum of all size classes, n = number of stems in size class i , k = the constant, 3.14, and r_i^2 = (size class i)².
- 4) Percent Frequency of Occurrence: (See equation 2).
- 5) Density:
$$D = \frac{B}{10,000} \quad (B)$$

Where D = density per hectare, B = total basal area of shrub stems for species A , B = total basal area or $10,000 \text{ m}^2$, and $10,000$ is the number of m^2 in a hectare.
- 6) Basal area:
$$B(A) = \frac{B(T)}{P} \quad (A)$$

Where $B(A)$ = basal area per hectare, $B(T)$ = total basal area, P = total plot size or $10,000 \text{ m}^2$, and D = density per hectare.

SEEDSUM Summary Program. --

7) Average Percent Cover: (See equation 1).

8) Percent Frequency: (See equation 2).

9) Density/ha: $D = (N/P)10,000$

Where D = density per hectare, N = total number of seedlings for species i ,
 P = total plot size or $80m^2$, and 10,000 is the number of m^2 in a hectare.

TREESUM Summary Program. --

10) Total Basal Area: $\Sigma[\pi(d(j)/2)^2]$

Where d = diameter of tree j , $d/2$ = radius of tree j , π = the constant 3.14, and Σ = sum of the area for all trees.

11) Average Percent Frequency: (See equation 2).

12) Total Distance: $S_{(t)} = \Sigma_{80} S_{(i)}$

Where $S_{(t)}$ = total distance in m between trees and the center points,
 $S_{(i)}$ = distance in m each tree is from the center point, and Σ_{80} = sum for 80 trees. (When no tree occurs in a quadrant consider the distance as 33m.)

13) Total Density/ha: $D_{(t)} = 10,000/(S_{(t)}/80)^2$

Where $D_{(t)}$ = the density per hectare of all trees, 10,000 = the number of m^2 in a hectare, and $(S_{(t)}/80)^2$ = the average area in m^2 between trees.

14) Species Density/ha: $D_{(i)} = N/M(D_{(t)})$

Where $D_{(i)}$ = species density/ha, N = number of trees of species i , M = total number of trees surveyed which is usually 80, and $D_{(t)}$ = total density of all trees per hectare.

15) Basal Area/ha: (See equation 6).

SEEDSUM Summary Program. --

7) Average Percent Cover: (See equation 1).

8) Percent Frequency: (See equation 2).

9) Density/ha: $D = (N/P)/10,000$

Where D = density per hectare, N = total number of seedlings for species

P = total plot size or $80m^2$, and 10,000 is the number of m^2 in a hectare.TREESUM Summary Program. --10) Total basal area: $\sum [(d_i/2)^2 \pi]$ where d = diameter of tree i, d/2 = radius of tree i, π = the constant3.14, and $\sum$ = sum of the area for all trees.

11) Average Percent Frequency: (See equation 2).

12) Total distance: $\sum_{i=1}^n \frac{1}{80} S_i^2$

where S = total distance in m between trees and the center points,

S_i = distance in m each tree is from the center point, and $\sum$ = sum for

80

80 trees. (When no tree occurs in a quadrant consider the distance as 2m.)

13) Total Density/ha: $D = 10,000 / \sum_{i=1}^n \frac{1}{80} S_i^2$

where D = the density per hectare of all trees, 10,000 = the number

of m^2 in a hectare, and $\sum_{i=1}^n \frac{1}{80} S_i^2$ = the average area in m^2 between trees.14) Species Density/ha: $D_i = N_i/W_i$ Where D_i = species density/ha, N_i = number of trees of species i, W =

total number of trees surveyed which is usually 80, and D = total density

(x)

of all trees per hectare.

15) Basal Area/ha: (See equation 1).

APPENDIX C.

Sample print-outs of the summary programs HERBSUM, SHRUSUM, SEEDSUM, and TREESUM.

APPENDIX C.

Sample of the collection of the Library of Congress, Smithsonian Institution, and the

and the

TRELSUM

EI-2 74 DATA

TREE DATA FOR STAND 1 20 POINTS SAMPLED

NO. OF POINTS	Total NO. OF STEMS	Total BASAL AREA M ²	PCENT FREQ.	DENS/ HECTARES	B.A./ HECTARES M ²	SPECIES	REL. FREQ.	REL. DENS.	REL. DOM.	IMPORT. VALUE
20	80	2.37	100	678.6	20.13	PIC MARIA	100.0	100.0	100.0	100.0
20	80	2.37	100	678.6	20.13	**TOTALS*	100.0	100.0	100.0	100.0

THE TOTAL DISTANCE IN M. IS 307.10

LIVING AND DEAD TREE STEMS TOGETHER - STAND 1

NO. OF POINTS	NO. OF STEMS	BASAL AREA	PCENT FREQ.	DENS/ HECTARES	B.A./ HECTARES	SPECIES	REL. FREQ.	REL. DENS.	REL. DOM.	IMPORT. VALUE
20	80	2.61	100	617.6	20.14	PIC MARIA	100.0	100.0	100.0	100.0
20	80	2.61	100	617.6	20.14	**TOTALS*	100.0	100.0	100.0	100.0

THE TOTAL DISTANCE IN M. IS 321.90

SAPLING DATA FOR STAND 1

NO. OF POINTS	NO. OF STEMS	BASAL AREA	PCENT FREQ.	DENS/ HECTARES	B.A./ HECTARES	SPECIES	REL. FREQ.	REL. DENS.	REL. DOM.	IMPORT. VALUE
18	34	.07	90	24.7	.05	PIC MARIA	100.0	100.0	100.0	100.0
18	34	.07	90	24.7	.05	**TOTALS*	100.0	100.0	100.0	100.0

THE TOTAL DISTANCE IN M. IS 1609.10

STATION 22.4 N AT STATION 24.01 JBT

STATION 22.4 N AT STATION 24.01 JBT

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STATION 22.4 N AT STATION 24.01 JBT

STATION 22.4 N AT STATION 24.01 JBT

SHRUSUM

SHRUBSUM ALL 73, 74-SHRUB DATA FOR STAND I 20 POINTS SAMPLED

BROWSE INDEX			Percent	Total	Total							
1	2	3	FREQ	NO. OF	BASAL	DENS/	B.A./		REL.	REL.	REL.	IMPORT.
			OF OCC	SHRUBS	AREA	HECTAIRE	HECTAIRE	SPECIES	FREQ.	DENS.	DOM.	VALUE
					M ²		M ²					
0.0	0.0	0.0	45	9	.00018	1125	.00249	BETULA GL	75.0	64.3	64.3	67.9
0.0	0.0	0.0	15	5	.00010	625	.00077	SALIX PUL	25.0	35.7	35.7	32.1
0.0	0.0	0.0	60	14	.00027	1750	.00325	**TOTALS**	100.0	100.0	100.0	100.0

SEEDSUM

FOREST FIRE RESEARCH-SEEDLING DATA

FOR STAND I 20 HECTARE PLOTS

POINTS	PCENT	NO. OF	AVE.	SEEDLINGS		REL.	REL.	REL.	REL.	IMPORT.
OF OCC	FREQ.	SEED.	COVER	D/HECTAIRE	SPECIES	FREQ.	DENS.	COV.	VALUE	
			%							
6	30.0	35	2.0	4375	PIC MARIA	100.0	100.0	100.0	100.0	
6	30.0	35	2.0	4375	**TOTALS**	100.0	100.0	100.0	100.0	

HERBSUM

EI 3 FOR 71-74

MOSS AND LICHEN DATA I

NO. OF POINTS	PCENT FREQ.	Total AMT. OF COVER	AVERAGE COVER %	SPECIES	REL. FREQ.	REL. COVER	IMPORT. VALUE
		%					
13	65	233	11.65	SPHAG SPP	22.0	58.4	40.2
10	50	74	3.70	PLEUR SCH	16.9	18.5	17.7
9	45	28	1.40	POLYTRICH	15.3	7.0	11.1
7	35	17	.85	FOLIOSE	11.9	4.3	8.1
4	20	19	.95	CLAD AMAU	6.8	4.8	5.8
4	20	13	.65	MOSS OTHE	6.8	3.3	5.0
4	20	7	.35	CLAD RANG	6.8	1.8	4.3
3	15	3	.15	CETR SPP	5.1	.8	2.9
2	10	2	.10	PARMELIA	3.4	.5	1.9
1	5	1	.05	CLAD GRA	1.7	.3	1.0
1	5	1	.05	AULOCO PA	1.7	.3	1.0
1	5	1	.05	HYLO SPLE	1.7	.3	1.0
59	295	399	19.95	**TOTALS**	100.0	100.0	100.0

HALF-SHRUB DATA FOR STAND I

NO. OF POINTS	PCENT FREQ.	Total AMT. OF COVER	AVERAGE COVER %	SPECIES	REL. FREQ.	REL. COVER	IMPORT. VALUE
		%					
14	70	50	2.50	VACC ULIG	27.5	16.9	22.2
9	45	76	3.80	OXY MICRO	17.6	25.8	21.7
10	50	69	3.45	VACC VITI	19.6	23.4	21.5
9	45	43	2.15	LED GROEN	17.6	14.6	16.1
5	25	29	1.45	LED DECUM	9.8	9.8	9.8
4	20	28	1.40	EMPET NIG	7.8	9.5	8.7
51	255	295	14.75	**TOTALS**	100.0	100.0	100.0

HERB DATA FOR STAND I

NO. OF POINTS	PCENT FREQ.	Total AMT. OF COVER	AVERAGE COVER %	SPECIES	REL. FREQ.	REL. COVER	IMPORT. VALUE
		%					
16	80	38	1.90	RUJUS CHA	51.6	62.3	57.0
8	40	14	.70	CALAMAG SP	25.8	23.0	24.4
2	10	4	.20	PETASITES	6.5	6.6	6.5
2	10	2	.10	CAREX SP	6.5	3.3	4.9
2	10	2	.10	EQUIS SYL	6.5	3.3	4.9
1	5	1	.05	HERB UNKNO	3.2	1.6	2.4
31	155	61	3.05	**TOTALS**	100.0	100.0	100.0

APPENDIX D.

Important equations used in the computer programs SCREEN, ORLOC, and CANAL.

Program SCREEN. --

The following discussion is quoted from Grigal and Ohmann (1975).

"The reduction of species was made objective and quantitative through the use of specific criteria in a computer program called SCREEN. The program is designed to give a relative idea of the 'importance' of each species in a large data set. The basic data set is represented by the matrix X , where x_{ij} is the frequency of the i th species in the j th stand. There are r species and c stands (notation follows Grigal and Goldstein 1971). SCREEN searches the matrix, ranks each species within that matrix based on each of six criteria, and then ranks each again based on the average of all criteria.

"The first criterion is occurrence (o), with those species occurring in the maximum number of sampled stands ranked highest. This is computed as the sum of stands containing a particular species divided by the total number of stands in the sample, or

$$o_i = (1/c) \sum_j y_{ij} \quad (1)$$

where $y_{ij} = 1$ if $x_{ij} > 0$ and $y_{ij} = 0$ if $x_{ij} = 0$, $i = 1, 2, \dots, r$, $j = 1, 2, \dots, c$.

"The next criterion is the arithmetic mean ($\bar{x}$) of the frequency of each species over all stands. This is computed as the sum of frequencies of all stands divided by the number of stands, or

$$\bar{x}_i = (1/c) \sum_j x_{ij} \quad (2)$$

"Next, each species is ranked on the basis of the ratio (u) between

APPENDIX D.

Important equations used in the computer program SCREEN, ORLOC, and

CANAL.

Program SCREEN.

The following discussion is quoted from Orloff and Orloff (1975).

"The reduction of species was made objective and quantitative through

the use of specific criteria in a computer program called SCREEN. The

program is designed to give a relative idea of the 'importance' of each

species in a large data set. The basic data set is represented by the

matrix X , where x_{ij} is the frequency of the i th species in the j th stand.

There are s species and n stands (notation follows Orloff and Orloff 1971).

SCREEN searches the matrix, ranks each species within that matrix based

on each of six criteria, and then ranks each stand on the average

of all criteria.

"The first criterion is occurrence (C_1), with those species occurring

in the maximum number of sampled stands ranked highest. This is computed

as the sum of stands containing a particular species divided by the total

number of stands in the sample, or

$$C_1 = \frac{1}{n} \sum_{j=1}^n \sum_{i=1}^s x_{ij} \quad (1)$$

where $x_{ij} = 1$ if $x_{ij} > 0$ and $x_{ij} = 0$ if $x_{ij} = 0$, $i = 1, 2, \dots, s$ or $j = 1, 2, \dots, n$.

"The next criterion is the arithmetic mean (C_2) of the frequency of each

species over all stands. This is computed as the sum of frequencies of

all stands divided by the number of stands, or

$$C_2 = \frac{1}{n} \sum_{j=1}^n \sum_{i=1}^s x_{ij} \quad (2)$$

"Next, each species is ranked on the basis of the ratio (C_3) between

the computed standard deviation of observations for that species and one predicted on the basis of the mean. The SD of frequency for a particular species over all stands is

$$s_i = ([\sum_j (x_{ij} - \bar{x}_i)^2] / c - 1)^{1/2} \quad (3)$$

This is divided by a deviation predicted on the basis of a linear relationship over all species between the mean frequency (Eq. 2) and the SD (Eq. 3). Thus the basis for ranking is

$$u_i = s_i / (\alpha + \beta \bar{x}_i), \quad (4)$$

where α and β are the least-square parameters of

$$s_i = \alpha + \beta \bar{x}_i \quad (5)$$

for all species. The mean and SD are highly correlated in such data sets (e.g., $r^2 = 0.80$ over all species for the natural stands; $r^2 = 0.70$ for the logged). Species were highly ranked when the ratio between their actual SD and that predicted from the least-square relationship was high. The premise in this ranking is that variable species may carry more information or be more exacting in their requirements than are species of low variability.

"The fourth criterion on which species were ranked in SCREEN is information content (h_i) based on presence and absence (Orlaci 1968). It is computed as the sum of the number of stands with a given species, times the natural log of the proportion that number is to the total number of stands, plus the number of stands without the species, times the log of that proportion, or

$$h_i = -\sum_{k=1}^2 g_{ik} \ln (g_{ik}/c) \quad (6)$$

where $g_{i1} = c - \sum_j y_{ij}$ and $g_{i2} = \sum_j y_{ij}$, where y_{ij} is defined in Eq. (1). Species having a high ranking based on this statistic vary in their distribution

the computed standard deviation of observations for that species and one predicted on the basis of the mean. The SD of frequency for a particular species over all stands is

$$s = \sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2} \quad (3)$$

This is divided by a deviation predicted on the basis of a linear relation-ship over all species between the mean frequency ($\bar{x}$) and the SD (s). Thus the basis for ranking is

$$r = \frac{s}{\bar{x}} \quad (4)$$

where s and $\bar{x}$ are the least-squares parameters of

for all species. The mean and SD are highly correlated in such data sets (e.g., $r^2 = 0.80$ over all species for the natural stands; $r^2 = 0.70$ for the

logged). Species were highly ranked when the ratio between their actual SD and that predicted from the least-squares relationship was high. The

provided in this ranking is that variable species may carry more information or be more exciting in their requirements than the species of low variability.

"The fourth criterion on which species were ranked in SCRS is their position content (or based on presence and absence) (O'Neill 1986). It is

computed as the sum of the number of stands with a given species, times the natural log of the proportion that number is to the total number of stands,

plus the number of stands without the species, times the log of that proportion, or

$$L = -\sum_{i=1}^n p_i \ln p_i - \sum_{i=1}^n (1-p_i) \ln (1-p_i) \quad (5)$$

where p_i and $1-p_i$ are defined in Eq. (1). Species having a high ranking based on this statistic vary in their distribution

among stands and thus may be more useful as a basis for recognizing plant communities.

"The fifth criterion is the relative contribution (*d*) made by each species in the calculation of interstand distance. This is computed as the sum over all possible combinations of two stands of the contribution that an individual species makes in the determination of total distance between those stands, or

$$d_i = (\sum_j \sum_k [(x_{ij}/v_j) - (x_{ik}/v_k)]^2)^{1/2}, j = 1, 2, \dots, c; k = 1, 2, \dots, c \quad (7)$$

where $v_j^2 = \sum_i x_{ij}^2$. Thus, if standard distance (Orloci 1967) is used to measure similarity between stands, then the species ranking high by this criterion are those which contribute most to determining that distance.

"The final criterion used to judge the relative importance of each species is the absolute weighting (*b*) of each species along the first five principal component axes. This is determined by calculating the eigenvectors of the correlation matrix based on frequencies of all species over all stands, and then summing the absolute values of the elements associated with each species for the first five vectors. If

$$z_{ij} = (x_{ij} - \bar{x}_i) / [\sum_j (x_{ij} - \bar{x}_i)^2]^{1/2}, \quad (8)$$

and E , with elements e_{im} , is the normalized eigenvector matrix of ZZ^T , then

$$b_i = \sum_{m=1}^5 |e_{im}|. \quad (9)$$

"The six criteria used in SCREEN resulted in a ranked list of species. The species to be used in subsequent analyses were selected from those ranking high on this list."

among stands and thus may be more useful as a basis for recognizing plant communities.

The fifth criterion is the relative contribution (%) made by each species in the calculation of interstand distance. This is computed as the sum over all possible combinations of two stands of the contribution that an individual species makes in the determination of total distance between those stands, or

$$d_k = \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n (d_{ij}^k - d_{ij})^2, \quad k=1, 2, \dots, 5 \quad (5)$$

where $d_k = \sum_{i=1}^n \sum_{j=1}^n d_{ij}^k$. Thus, if standard distance (Ostrik 1967) is used to measure similarity between stands, then the species ranking high by this criterion are those which contribute most to determining that distance. The first criterion used to judge the relative importance of each species is the absolute weighting (%) of each species along the first five principal component axes. This is determined by calculating the eigenvalues of the correlation matrix based on frequencies of all species over all stands, and then summing the absolute values of the elements associated with each species for the first five vectors. It

$$w_k = 100 \cdot \frac{e_k}{\sum_{k=1}^5 e_k} \quad (6)$$

and E_k with elements e_k is the normalized eigenvector matrix of E . Then

$$R = \sum_{k=1}^5 w_k \quad (7)$$

The six criteria used in SCREI resulted in a ranked list of species. The species to be used in subsequent analyses were selected from those ranking high on this list.

Program CANAL. --

The following discussion is quoted from Grigal and Goldstein (1971). This program is used in the ordination analysis of the cluster groups.

"Each set of clusters is ordinated by means of canonical analysis (Seal 1964). The objective of the canonical analysis is to study the relationship between the groups making up each set. Let us assume the original data have been divided into h groups of stands. Each group is a subset, X_k , of the original data set X . The number of stands in the k th group is n_k . The mean amount of species i in the k th group is

$$\bar{x}_{i(k)} = \frac{\sum_{j \in X_k} x_{ij}}{n_k}$$

The 'within' variance-covariance matrix for the set of groups is

$$\Sigma = \frac{1}{c-h} \sum_k \mathbf{R}_k \mathbf{R}_k^T$$

where

$$\mathbf{R}_k = \{r_{ij(k)}\}, i = 1, 2, \dots, r; j \in X_k$$

and

$$r_{ij(k)} = x_{ij(k)} - \bar{x}_{i(k)}$$

The mean amount of species i in the set X is

$$\bar{x}_i = \frac{1}{c} \sum_j x_{ij}$$

The 'between' variance-covariance matrix for the set of groups is

$$\Xi = \frac{1}{h-1} \mathbf{S} \mathbf{S}^T$$

where

$$\mathbf{S} = \{s_{ik}\}, i = 1, 2, \dots, r; k = 1, 2, \dots, h$$

and

$$s_{ik} = n_k^{1/2} (\bar{x}_{i(k)} - \bar{x}_i)$$

In order to find the positions of the groups in canonical space, we solve for $\mathbf{E} = \{e_i\}$, the set of eigenvectors of the system

$$(\mathbf{P} - \lambda_i \mathbf{W}) \mathbf{e}_i = 0$$

where $\mathbf{P} = (h-1)\Xi$, $\mathbf{W} = (c-h)\Sigma$

and λ_i is the eigenvalue corresponding to the eigenvector e_i . The matrix

The following discussion is quoted from Oring and Goldstein (1971). This program is used in the ordination analysis of the cluster groups. Each set of clusters is ordinated by means of canonical analysis (Zar 1964). The objective of the canonical analysis is to study the relationships between the groups making up each set. Let us assume the original data have been divided into k groups of stands. Each group is a subset, X_k , of the original data set X . The number of stands in the k th group is n_k . The mean amount of species i in the k th group is

$$\bar{x}_{ik} = \frac{\sum_{j=1}^{n_k} x_{ijk}}{n_k}$$

The within-group variance-covariance matrix for the set of groups is

$$W = \frac{1}{n} \sum_{k=1}^K n_k (\bar{x}_k - \bar{x})(\bar{x}_k - \bar{x})'$$

where

$$\bar{x}_k = (\bar{x}_{1k}, \bar{x}_{2k}, \dots, \bar{x}_{pk})'$$

The mean amount of species i in the set X is

$$\bar{x}_i = \frac{\sum_{k=1}^K n_k \bar{x}_{ik}}{n}$$

The between-group variance-covariance matrix for the set of groups is

$$B = \frac{1}{n} \sum_{k=1}^K n_k (\bar{x}_k - \bar{x})(\bar{x}_k - \bar{x})'$$

where

$$\bar{x} = (\bar{x}_1, \bar{x}_2, \dots, \bar{x}_p)'$$

In order to find the positions of the groups in canonical space, we solve

for $E = \lambda I$, the set of eigenvalues of the system

$$(B - \lambda W) = 0$$

where $B = B - \lambda W$ and I is the identity matrix.

and λ is the eigenvalue corresponding to the eigenvector E . The matrix

giving the positions of the groups relative to the canonical axes is

$$Y = V^T F$$

where

$$f_i = \left(e_i^T \frac{W}{n-h} e_i \right)^{-\frac{1}{2}} e_i$$

and

$$V = \{v_{ik}\}, i = 1, 2, \dots, r; k = 1, 2, \dots, h$$

$$v_{ik} = \bar{x}_{i(k)} - \bar{x}_i$$

The individuals in the sample are regarded as points in p dimensional (Cartesian) space. The analysis, in this context, amounts to identifying the clusters of points in space. It should not be overlooked, however, that 'clustering' techniques will produce a sorting of individuals into groups irrespective of the existence of natural clusters of individuals within the sample.

1. Data matrix

Biological data are usually presented in row tables in the printed form. The p rows represent species and the n columns correspond to stands. The entries in any one column represent a vector which defines the position of a corresponding stand as a point in space. A set of row averages (mean vector) contains the co-ordinates of the average stand (or centroid) of the sample. The i th value in the mean vector in the average space is the i th row,

$$\bar{x}_i = \frac{1}{n} \sum_{j=1}^n x_{ij}$$

the quantity

$$x_i = \sqrt{\sum_{j=1}^n x_{ij}^2}$$

is the length of the i th position (column) vector.

2. Distance coefficients

The systematic classification presented in this paper requires the definition of a structure upon the sample by means of a metric parameter. Absolute distance (D), standard distance (D^*), and the angle (α) enclosed

giving the positions of the groups relative to the canonical axes is

$$x = x_0 + \Delta x$$

or

$$\tilde{x} = \left(x_0 + \frac{W}{L} x \right) e^{-\frac{W}{L} x}$$

where

$$V = \{v_1, v_2, \dots, v_n\} = \{x_1, x_2, \dots, x_n\}$$

and

Program ORLOC. --

The following discussion is quoted from Orloci (1967). This program is used in the cluster analysis of individual stands.

"The agglomeration procedure is most amenable to explanation when the n individuals (stands in our case) defined by p attributes (species in our case) are regarded as n points in p dimensional (Cartesian) space. The analysis, in this context, amounts to identifying the clusters of points in space. It should not be overlooked, however, that 'clustering' techniques will produce a sorting of individuals into groups irrespective of the existence of natural clusters of individuals within the sample.

1. *Data table*

"Phytosociological data are usually presented in $p \times n$ tables; in the present case, the p rows represent species and the n columns correspond to stands. The entries in any one column represent a vector which defines the position of a corresponding stand as a point in space. A set of row averages (mean vector) contains the co-ordinates of the average stand (or centroid) of the sample. The e th value in the mean vector is the average score in the e th row,

$$\bar{X}_e = \frac{\sum_{j=1}^n X_{e,j}}{n}$$

the quantity,

$$V_j = \sqrt{\left[\sum_{e=1}^p X_{e,j}^2 \right]}$$

is the length of the j th position (column) vector.

2. *Distance coefficients*

"The agglomerative classification presented in this paper requires the imposition of a structure upon the sample by means of a metric parameter. Absolute distance (D), standard distance (D'), and the angle (α) enclosed

The following discussion is quoted from Orlock (1961). This program is used in the cluster analysis of individual stands.

"The agglomeration procedure is most amenable to explanation when the individuals (stands in our case) defined by p attributes (species in our case) are regarded as n points in a p -dimensional (Cartesian) space. The analysis, in this context, amounts to identifying the clusters of points in space. It should not be overlooked, however, that 'clustering' techniques will produce a sorting of individuals into groups irrespective of the existence of natural clusters of individuals within the sample.

1. Data matrix

Physiological data are usually presented in two tables in the present case. The p rows represent species and the n columns correspond to stands. The entries in any one column represent a vector which defines the position of a corresponding stand as a point in space. A set of row averages (mean vector) contains the co-ordinates of the average stand (or centroid) of the sample. The k th value in the mean vector is the

$$\bar{x}_k = \frac{\sum_{i=1}^n x_{ik}}{n}$$

average score in the k th row,

$$r_k = \sqrt{\sum_{i=1}^n x_{ik}^2}$$

the quantity,

is the length of the j th position (column) vector.

2. Distance coefficients

The agglomerative classification presented in this paper requires the imposition of a structure upon the sample by means of a metric parameter. Absolute distance (D), standard distance (D'), and the angle (α) enclosed

between position vectors are considered in this connection. The geometric meaning of these measures is apparent from Fig. 1 on inspection.

Absolute distance (the shortest distance between two points) is calculated from the unstandardized species scores.

$$D_{ij} = \sqrt{\sum_{k=1}^K (X_{ik} - X_{jk})^2}$$

(The expression in the case of presence-absence scores reduces to $D_{ij} = \sqrt{\sum_{k=1}^K (X_{ik} - X_{jk})^2}$.)

The symbols in the latter expression are those regularly used in 2x2 contingency tables.)

contingency tables.)

"Absolute distance reflects differences between stands in the absolute quantity of the species present. It follows, therefore, that two stands with no species in common (C, E in Fig. 1) may appear by this measure more similar, if the scores on the species are generally low, than two other stands (A, B in Fig. 1) of identical species composition but



FIG. 1. The geometry of unstandardized X_{ik} . For any two stands the expression for absolute distance is

greatly different proportion of the species present. This anomaly could be prevented by using the arc corresponding to the angle (α) between the position vectors as a substitute for distance in defining stand relationships. By this measure, stands i and k are more distinct than stands j and h . The arc may be used as a substitute for distance to correct the anomaly, but it is not practical to work with, because it does not satisfy the common definition of distance. A measure which qualifies in this respect and also is only dependent on α is the chord (D') corresponding to the angle α . The standard distance is thus defined as the length of the chord,

$$D'_{j,k} = 2 \sin \frac{\alpha_{j,k}}{2}$$

connecting two points on the surface of a sphere of unit radius. The expression of D' is further equal to

$$\begin{aligned} & \sqrt{[2(1 - \cos \alpha_{j,k})]} \\ &= \sqrt{\left[2 \left(1 - \frac{\sum_{e=1}^p X_{e,j} X_{e,k}}{V_j V_k} \right) \right]} \\ &= \sqrt{\left[\sum_{e=1}^p \left(\frac{X_{e,j}}{V_j} - \frac{X_{e,k}}{V_k} \right)^2 \right]} \end{aligned}$$

"Evidently, the simplest way to calculate standard distance is by the distance formula on the basis of standardized species scores; standardization is of the type $X_{e,j}/V_j$. The length of the position vectors is thus altered to be equal to unity. The angle (α) between the position vectors, however, is not affected by this type of standardization. The ecological significance of standardization to position vectors of unit length is readily conceived from Fig. 1: the original stands (i, k, j, h) are replaced by synthetic stands represented in the analysis by points (i', k', j', h') located at unit distance from the co-ordinate origin. The points are thus placed on the surface of a sphere, representing a synthetic state

greatly different proportion of the species present. This anomaly could be prevented by using the arc corresponding to the angle (α) between the position vectors as a substitute for distance in defining stand relationships. By this measure, stands X and Y are more distinct than stands Y and Z . The arc may be used as a substitute for distance to correct the anomaly, but it is not practical to work with, because it does not satisfy the common definition of distance. A measure which satisfies in this respect and also is only dependent on α is the chord (C) corresponding to the angle α . The standard distance is thus defined as the length of the chord.

$$C = 2 \sin \frac{\alpha}{2}$$

Connecting two points on the surface of a sphere of unit radius. The expression of C is further equal to

$$C = \sqrt{2 \left(1 - \frac{\sum_{i=1}^n x_i y_i}{n} \right)}$$

Obviously, the simplest way to calculate standard distance is by the distance formula on the basis of standardized species counts; standard distance is of the type L_{ij} . The length of the position vectors is thus altered to be equal to unity. The angle (α) between the position vectors, however, is not affected by this type of standardization. The ecological significance of standardization to position vectors of unit length is readily conceived from Fig. 1: the original stands (X, Y, Z) are replaced by synthetic stands represented in the analysis by points (X', Y', Z') located at unit distance from the co-ordinate origin. The points are thus placed on the surface of a sphere, representing a synthetic state

of the vegetation in which the individual stands only differ among themselves by the distribution of a unit quantity

$$\left(\sum_{j=1}^p x_{e,j}^2 / V_j^2 = 1 \right)$$

among the constituent species.

"The relationship of two groups of points (m, l) is defined by the distance between their centroids,

$$D_{m,l} = \sqrt{\sum_{e=1}^p (X_{e,m} - X_{e,l})^2}$$

The mean scores $(\bar{X}_e)$ are calculated from either standardized or unstandardized scores (dependent on the analysis). Calculation of distance between centroids, however, can be very tedious and may require large computer storage capacity to retain the raw data. A comparison, however, can be achieved on the basis of the average distance between groups (which is not the same as the distance between centroids), calculated directly from the distances:

$$\bar{D}_{m,l} = \frac{\sum_{j=1}^{k_m} \sum_{h=1}^{k_l} D_{j,h}}{k_m k_l}$$

where k is the number of individuals in one group.

1. *Definition of within-group dispersion*

"Edwards and Cavalli-Sforza (1965) used the sum of squared distances from the centroid of the group to derive a measure for the within-group dispersion. This quantity,

$$Q_m = \sum_{j=1}^{k_m} v_j^2$$

can also be calculated from the distances,

$$Q_m = \frac{\sum_{j,h=1}^{k_m} D_{j,h}^2}{2k_m}$$

$$= \frac{\sum_{j=1}^{k_m-1} \sum_{h=j+1}^{k_m} D_{j,h}^2}{k_m}$$

of the vegetation in which the individual stands only differ among them-

self by the distribution of a unit quantity

$$\left(\frac{\sum_{i=1}^k x_i^2}{n} - 1 \right)$$

among the constant species.

"The relationship of the groups of points ($k=1$) is defined by the

distance between their centroids

$$D_{12} = \sqrt{\left(\bar{x}_1 - \bar{x}_2 \right)^2 + \left(\bar{y}_1 - \bar{y}_2 \right)^2}$$

The mean scores ($\bar{x}$) are calculated from either standardized or unstandard-

ized scores (dependent on the analysis). Calculation of distance between

centroids, however, can be very tedious and may require large computer

storage capacity to retain the raw data. A comparison, however, can be

achieved on the basis of the average distance between groups (which is not

the same as the distance between centroids), calculated directly from the

$$D_{12} = \frac{\sum_{i=1}^k \sum_{j=1}^k D_{ij}}{k(k-1)}$$

where k is the number of individuals in one group.

1. The distance of within-group deviation

"Edwards and Cavalli-Sforza (1965) used the sum of squared distances

from the centroid of the group to derive a measure for the within-group

$$Q_1 = \frac{\sum_{i=1}^k w_i^2}{n}$$

can also be calculated from the distances.

$$Q_2 = \frac{\sum_{i=1}^k \sum_{j=1}^k D_{ij}^2}{2k}$$

$$Q_3 = \frac{\sum_{i=1}^k \sum_{j=1}^k D_{ij}^2}{k(k-1)}$$

where k is the number of individuals in the group. The quantity Q/k then is the average dispersion within a group.

"If the sample sum of squares is designated as Q_s , the ratio

$$I = \frac{\sum_{m=1}^G Q_m}{Q_s}$$

(where G is the number of groups into which the sample is divided) can be used as a measure of the overall within-group heterogeneity in the sample of G groups. The quantity,

$$E = \frac{Q_s - \sum_{m=1}^G Q_m}{Q_s} = 1 - I$$

is an expression of overall differences between groups, because when every individual is treated as a separate unit, $E = 1$, and when all individuals are combined to form a single group, $E = 0$. An optimal agglomeration can be achieved when I is minimized (or E is maximized) at each clustering cycle.

4. Optimal agglomeration

"The technique presented in this paper includes clustering in successive cycles, gradually uniting the individuals to form larger and larger groups in a manner such that the E value is a maximum at each clustering cycle. Because the goal is to construct a hierarchy of dichotomous branching, not more than two entities (individuals or groups) are united per group per clustering cycle, and two entities are united only if the increase of the within-group dispersion (measured by Q) by their fusion is less than it would be by uniting either of the two with another entity in the sample. In other words, if A , B , C and D are entities to be classified and Q_A , Q_B , Q_C , Q_D represent the within-group sum of squares, and if $Q_{AB} - (Q_A + Q_B)$ is not

where k is the number of individuals in the group. The quantity Q_k then is the average dispersion within a group.

If the sample sum of squares is designated as Q , the ratio

$$1 - \frac{\sum_{k=1}^K Q_k}{Q}$$

(where K is the number of groups into which the sample is divided) can be used as a measure of the overall within-group heterogeneity in the sample of K groups. The quantity

$$E = 1 - \frac{\sum_{k=1}^K Q_k}{Q}$$

is an expression of overall difference between groups, because when every individual is treated as a separate unit, $E = 1$, and when all individuals are combined to form a single group, $E = 0$. An optimal aggregation can be achieved when E is maximized (or E is maximized) at each clustering cycle.

4. Optimal aggregation

The technique presented in this paper includes clustering in successive cycles, gradually uniting the individuals to form larger and larger groups. In a manner such that the E value is a maximum at each clustering cycle. Because the goal is to construct a hierarchy of dichotomous branching, not more than two entities (individuals or groups) are united per group per clustering cycle, and two entities are united only if the increase of the within-group dispersion (measured by Q) by their fusion is less than if would be by uniting either of the two with another entity in the sample. In other words, if Q_1 , Q_2 , and Q_3 are entities to be classified and Q_4 is not, we recommend the within-group sum of squares, and if $Q_4 - (Q_1 + Q_2)$ is not

larger than either $Q_{AC} - (Q_A + Q_C)$ or $Q_{AD} - (Q_A + Q_D)$ then A is united with B to form a higher group AB if $Q_{AB} - (Q_A + Q_B)$ is also not larger than either $Q_{BC} - (Q_B + Q_C)$ or $Q_{BD} - (Q_B + Q_D)$. If these conditions are false, then A is fused with another entity and the fusion is tested in a manner as in the case of AB . The process is continued until a valid fusion is found or all fusions with A are tested and rejected. The ambiguity, as for instance,

$$Q_{AB} - (Q_A + Q_B) = Q_{AC} - (Q_A + Q_C)$$

is resolved by taking the first value encountered in the process to be smallest. The number of trial fusions to be considered in any clustering cycle is $k(k-1)/2$.

"In comparison to centroid sorting (Ducker et al. 1965) whereby the mutually closest entities are fused in pairs in each clustering cycle, optimal agglomeration requires smaller computer capacity than centroid sorting; whereas the locations of the data matrix can be overwritten by the distance matrix from which all subsequent steps can be derived by simple manipulations in optimal agglomeration, centroid sorting requires the original data to be retained to calculate centroid distances (unless these are replaced by the average distances between the groups).

"Representation of the hierarchy is made in the form of a dendrogram in which the stems are joined at the corresponding Q/k values. The overall heterogeneity of the stems can be evaluated at any level of the hierarchy by the ratio I . This ratio is also a parameter of classification inefficiency because, when classification is most intensive, i.e. each individual represents a different unit, the value of I is zero. (The quantity $E = 1 - I$ is then an expression of classification efficiency.)

larger than either $G_1 = G_2 + G_3$ or $G_2 = G_1 + G_3$, then A is united with B to form a higher group AB if $G_{AB} = G_1 + G_2$ is also not larger than either $G_1 = G_2 + G_3$ or $G_2 = G_1 + G_3$. If these conditions are false, then A is fused with another entity and the fusion is tested in a manner as in the case of A. The process is continued until a valid fusion is found or all fusions which are tested and rejected. The ambiguity, as the instance

$$G_1 - G_2 + G_3 = G_2 - G_1 + G_3$$

is resolved by testing the first value encountered in the process to be smallest. The number of trial fusions to be considered in any clustering cycle is $(n-1)/2$.

"In comparison to centroid sorting (Buckley et al., 1982) whereby the mutually closest entities are fused in pairs in each clustering cycle, optimal agglomeration requires smaller computer capacity than centroid sorting, whereas the locations of the data matrix can be overwritten by the distance matrix from which all subsequent steps can be derived by simple manipulations in optimal agglomeration, centroid sorting requires the original data to be retained to calculate centroid distances (unless these are replaced by the average distances between the groups).

"Representation of the hierarchy is made in the form of a dendrogram in which the stems are joined at the corresponding G_k values. The overall heterogeneity of the stems can be evaluated at any level of the hierarchy by the ratio λ . This ratio is also a parameter of classification inefficiency because, when classification is most intensive, i.e. each individual represents a different unit, the value of λ is zero. (The quantity $\lambda = 1 - \lambda$ is then an expression of classification efficiency.)

"If a probabilistic test of the assumption that the G groups (stems) represent independent (random) samples of a multivariate normal universe is appropriate, the classification may be terminated after fusion of only those stems whose mean vectors are not significantly different. When, however, a probabilistic comparison of the stems is inappropriate, any reasonable rule to terminate the hierarchy is accepted."

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"It is a probabilistic test of the assumption that the 6 groups (states) represent independent (random) samples of a multi-variate normal universe. If appropriate, the classification may be terminated after fusion of only those states whose mean vectors are not significantly different. When, however, a probabilistic comparison of the states is inappropriate, any reasonable rule to terminate the hierarchy is acceptable."

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